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UK Coal Resource for New Exploitation Technologies

Final Report

Sustainable Energy & Geophysical Surveys Programme

Commissioned Report CR/04/015N

BRITISH GEOLOGICAL SURVEY

Commissioned Report CR/04/015N

UK Coal Resource for New Exploitation Technologies

Final Report

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Cleat in coal

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EXECUTIVE SUMMARY

This focus of this report are the UK coal resources available for exploitation by the new technologies of Underground Coal Gasification, Coalbed Methane production and Carbon Dioxide Sequestration. It also briefly considers the potential for further underground and opencast mining and the extraction of methane from working and closed mines. The potential for mining was mainly considered because it has a bearing on the scope for the new exploitation technologies rather than to identify resources or potential mine development areas. The report covers the UK landward area and nearshore areas, although information on the extent of underground mining was not available for the nearshore areas.

This work was carried out by the British Geological Survey, with the assistance of Wardell Armstrong and Imperial College, London. It represents a summary of the results of the Study of the UK Coal Resource for New Exploitation Technologies Project, carried out for the DTI Cleaner Coal Technology Programme (Contract No. C/01/00301/00/00) under the management of Future Energy Solutions (Agreement No. C/01/00301/00/00).

Coalbed methane production can be subdivided into three categories:

Methane drained from working mines, known as Coal Mine Methane (CMM), has been exploited in the UK since at least the 1950s. Currently all working mines except Daw Mill and Ellington drain methane. It is used to generate electricity at Harworth, Tower and Thoresby collieries and in boilers at Welbeck, Kellingley and Ricall/Whitemoor collieries. There is potential to increase the exploitation of CMM in the UK but this is mainly a question of economics. There is also an environmental case for further utilisation, as methane is an important greenhouse gas, 23 times more powerful than carbon dioxide on a mass basis.

Methane drained from abandoned mines, known as Abandoned Mine Methane (AMM), is a methane-rich gas that is obtained from abandoned mines by applying suction to the workings. The fuel gas component consists primarily of methane desorbed from seams surrounding the mined seam(s). These unmined seams have been de-stressed and fractured by the collapse of overlying and underlying strata into the void left by the extracted seam(s). Currently AMM is being exploited at sites in North Staffordshire (Silverdale Colliery), the East Midlands (Bentinck, Shirebrook and Markham collieries) and Yorkshire (Hickleton, Monk Bretton and Wheldale collieries). The methane-rich gas is used for electricity generation or supplied to local industry for use in boilers and kilns. Over the last few years, the fledgling UK AMM industry has started to ascend a learning curve. However, it has suffered a major setback since the wholesale price of electricity fell under the New Electricity Trading Arrangements and AMM does not currently qualify as renewable energy in the UK.

Coalbed methane produced via boreholes from virgin coal seams, known as Virgin Coalbed Methane (VCBM), has been the subject of significant exploration effort in Lancashire, North Wales, South Wales and Scotland. The best production of gas and water from a single well is understood to be from the project at Airth, north of Falkirk in Scotland. However, this is not economic at present. The main reason for the slow development of VCBM in the UK is perceived to be the widespread low permeability of UK coal seams, although little work has been carried out in the UK on coal permeability, or to truly identify the reasons for the lack of success. This must be overcome before the otherwise significant resource bases in the Clackmannan Syncline, Canonbie, Cumbria, South

Lancashire, North Wales, North Staffordshire and South Wales coalfields can be exploited. A technological breakthrough is required to overcome the likely widespread low permeability in the UK Carboniferous coal seams. Otherwise, at best, production will probably be limited to niche opportunities in areas where high seam permeability exists. The criteria used to define and map the location of VCBM resources are as follows:

- Coal seams greater than 0.4 m in thickness at depths >200 m
- Seam gas content >1m^3/tonne
- 500 metres or more horizontal separation from underground coal workings
- Vertical separation of 150m above and 40 m below a previously worked seam
- Vertical separation of >100 m from major aquifers, and
- Vertical separation of >100 m from major unconformities

Areas with a CMM resource (current underground coal mining licences) were excluded. Note that the presence of a CBM resource does not imply permeability in the coal seams or that the resource can be recovered economically now or at any time in the future. Using these criteria resource areas were defined and represented on the maps. The total VCBM resource of these areas is thought to be about 2,900 x 10^9 m^3 (about 29 years of UK natural gas consumption).

Underground coal gasification (UCG) is the process whereby the injection of oxygen and steam/water via a borehole results in the partial *in-situ* combustion of coal to produce a combustible gas mixture consisting of CO_2, CH_4, H_2 and CO, the proportions depending on temperature, pressure conditions and the reactant gases injected. This product gas is then extracted via a producing well for use as an energy source. All previous trials of this technology in the UK took place in the 1950's or before, e.g. Durham (1912), Newman Spinney (1949-1956) and Bayton (c.1955), although this country is well placed for UCG, with large reserves of indigenous coal both onshore and offshore. The main criteria used for the delineation and mapping of resource areas with potential for UCG were:

- Seams of 2 m thickness or greater
- Seams at depths between 600 and 1200 m from the surface
- 500 m or more horizontal and vertical separation from underground coal workings and current coal mining licences, and
- Greater than 100 m from major aquifers

While seams outside these depth and thicknesses criteria are known to support UCG, the criteria were chosen for this generic study on economic and environmental grounds as described later in this report. The establishment of these criteria do not rule out UCG projects in shallower or thinner seams, if local site specific factors support it.

Mapping of the potential UCG resource has identified large areas suitable for UCG, particularly in Eastern England, Midland Valley of Scotland, North Wales, Cheshire Basin, South Lancashire, Canonbie, the Midlands and Warwickshire. Potential also exists in other coalfields but on a smaller scale; this is often limited by the extent of former underground coal mining activities. The total area where coals are suitable for gasification is approximately 2.8 x 10^{9}m^2. Where the criteria for UCG are met, the minimum volume of coal available for gasification, calculated assuming only one 2 m thick seam meets the criteria across each area, is approximately 5,698 x $10^6 m^3$ (~7 Btonnes). Using an average of the total thickness of coals that meet the criteria across each area gives a more realistic resource figure of 12,911 x $10^6 m^3$ (~17 Btonnes).

Carbon dioxide (CO_2) sequestration onto coal is a technology that has been proposed as a greenhouse gas mitigation option. Carbon dioxide has an affinity to be adsorbed onto coal and this affinity is greater than that of methane. Thus it has been proposed that CO_2 could be used to enhance coalbed methane production by displacing the methane from sorption sites on coal. Furthermore, nitrogen has the potential to enhance coalbed methane production, by lowering the partial pressure of methane in the cleat and causing methane to desorb faster from the sorption sites as well as sweeping the gases from the natural coal fracture system. Thus it may be possible to enhance coalbed methane production using flue gas (essentially a mixture of nitrogen and CO_2) and thus bypass the expensive step of separating the CO_2 from flue gases. If the main objective, however, is CO_2 sequestration rather than methane production then separation of the flue gases may be worthwhile.

This technology is at a very early stage of development. A trial has been conducted in the San Juan Basin, USA, but the results were inconclusive as, from a research perspective, the trial was brought to an end prematurely. Further research programmes are under way, but conclusive results are not yet available. However, any CO_2 sequestration project that relies on injecting CO_2 into coal seams will require significant coal seam permeability and this appears to be a major issue in the UK (see VCBM above). Furthermore, if there was a requirement for permanent sequestration of CO_2 on coal seams, this would render them unminable and ungasifiable (because the CO_2 would be released). Any future mining of such coals would require re-capture and sequestration of the stored CO_2.

Because of the major uncertainties surrounding this technology, no areas specifically suitable for it have been identified. Instead, a general assumption has been made that where coal seam are at depths below 1,200 m they are unlikely to be mined or gasified and therefore may have some theoretical potential for CO_2 sequestration, providing that other issues, such as low seam permeability, can be overcome. Large areas where coal is below 1,200 m occur in the UK, particularly in the Cheshire Basin and Eastern England.

In summary:

- The UK has vast resources of onshore coal suitable for underground gasification and VCBM production.
- CMM could be utilised at certain mines where it is currently drained, but vented to the atmosphere.
- The UK has a fledgling AMM industry, but its future growth will depend on factors such as electricity price and its renewable status.
- The total is about 29 years of UK gas production, but the intrinsic permeability of typical UK coal seams is currently a major impediment to its exploitation.
- The estimated onshore resource for UCG is 17 Btonnes with large areas in Eastern England, Scotland and the Midlands suitable.
- CO_2 sequestration technology is immature at present and its potential application in the UK cannot be assessed. However, there are vast areas of coal at depths below 1,200 m that are possibly too deep for mining and *in situ* gasification.

1 FOREWORD

The principal aim of this project was to assess the potential of the UK onshore coal resources for both exploitation by conventional (mining) and new technologies and to represent this on a series of maps that would identify prospective areas. The mining technologies include underground and opencast mining, coal mine methane (CMM) and abandoned mine methane (AMM) and the new technologies include underground coal gasification (UCG), virgin coalbed methane (VCBM) and coal seam-related carbon dioxide (CO_2) sequestration.

This report represents a summary of the results of the Study of the UK Coal Resource for New Exploitation Technologies Project, carried out for the DTI under the management of Future Energy Solutions (Agreement No. C/01/00301/00/00). This work was undertaken by the British Geological Survey, with the assistance of Wardell Armstrong and contributions from Imperial College, London. The work was initiated on 15 April 2002 and completed in October 2003.

The scope of the work encompassed the following topics:

- Compilation of existing datasets
- Establishing the criteria for mapping the conventional and new technologies
- Databasing of key coal boreholes
- Production of maps to identify the potential for extracting coal and methane using conventional and new technologies
- External consultations, discussions and meetings
- Proposals for future studies to improve and extend the resource exploitation maps
- Reporting

The deliverables of this study are as follows:

- A series of 1:100,000 scale paper maps showing the conventional and new technologiesMontage paper map of the UK at 1:1,750,000 scale, with 1:600,000 inset maps, summarising the main features of these smaller scale maps
- Digital version of the above maps as an Adobe pdf fileA final reportA public domain reportA project summary
- Presentation of the results of the study at a workshop at the DTI in October 2003

As part of this work consultations were held with Alkane Energy and the Coal Authority at which example maps were presented for their comments and approval, which was given.

2 INTRODUCTION

The UK contains extensive resources of coal, both at surface and in the subsurface. It is estimated that onshore these surface and subsurface deposits cover an area of approximately 40,000 km^2. The major coalfields of the UK are of Carboniferous age. The exceptions to this are small accumulations of Tertiary lignites in Devon and Northern Ireland 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 Scottish Coal Measures Groups, divisible into lower, middle and upper units known as formations (Figure 1). In Scotland and north east England there are coalfields of Westphalian age, but there are also important coal-bearing strata in the earlier Carboniferous (Namurian and Dinantian) rocks (Figure 1). The term Coal Measures Group and Lower, Middle and Upper Coal Measures are formally defined lithostratigraphical names with specific ages so, in this report, they are generally replaced by the generic term 'coal-bearing strata' to include all the coal-bearing units regardless of age.

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 (Figure 2). Other important coalfields include South Wales, Kent and those in the Midland Valley of Scotland. The coalfield names generally refer to the surface or outcrop distribution of the coal-bearing strata and much is known about the coal seam distribution, thickness and overall properties in these areas as a result of extensive former mining and geological mapping. They still represent areas of interest for the conventional, mining technologies. However, there are also significant subsurface (concealed) extensions to the coalfields, where coals are buried beneath younger strata. In these areas mining is in many cases more limited and tends to be restricted to the less deeply buried parts. The only data available from the unmined areas tends to be from boreholes and seismic reflection surveys; hence less is known about the geology. It is these areas that are likely to be of major interest for the new technologies.

2.1 AIMS OF THE PROJECT

The principal aim of the study was to define areas suitable for the exploitation of UK coal resources. The focus of the study was directed mainly towards the new technologies, although the mining technologies were also considered.

This study required the definition of a set of criteria that describe the presence of a coal resource suitable for exploitation by each technology, followed by a review of the geological data to determine, by coalfield and region, which areas of coal are suitable for the exploitation by each technology. Maps were then produced identifying which exploitation technologies are best suited to extracting coal and/or methane at various horizons and localities.

The project covers all onshore coalfields in the UK, including Northern Ireland. It includes coal under estuaries and near-shore areas that can practically be reached by land-based directional drilling. No data more than 5 km offshore were considered. The study takes the form of a general evaluation rather than a detailed examination of individual coal seams. Planning and hydrogeological issues were not considered in this study. This report also proposes how such a review might be further developed and extended to the offshore UK waters.

In this report the term 'Mining Technologies' refers not only to opencast and underground mining, but also coal mine methane (CMM) and abandoned mine methane (AMM) which require active and former mining respectively. The term 'New Technologies' refers to underground coal gasification (UCG), virgin coalbed methane (VCBM) and coal-related CO_2 sequestration.

2.2 METHODOLOGY

The following methodology was applied:

- Establish the criteria that define the presence of a suitable coal resource for exploitation by each of the mining and new technologies
- Identify and compile suitable datasets
- Establish areas of past and present activity for mining and the current licensed areas for all fossil fuel extraction (coal, oil and gas)
- Compile a borehole database identifying gross thickness and depth of coal seams
- Establish a database of the UK coal resource and identify and map areas where resources exist
- Apply the resource criteria to the UK coal-bearing strata
- Assess the potential for future utilisation of the resource by the various exploitation techniques
- Propose future studies to improve and extend the resource exploitation maps

These are discussed in more detail in the following sections.

3 RANKING AND RISKING OF COAL RESOURCES

A **coal resource** is defined here as: "*That amount of coal present in such form and quantity that there may be prospects for its eventual extraction*". Such a resource can be either identified or undiscovered (Figure 3). An identified coal resource can be reported in terms of Inferred, Indicated and Measured categories (Figure 3). A **coal reserve** is defined here as: "*A resource that can be economically recovered now using present-day technologies*". Thus resources and reserves are very different - in essence a resource defines what is in the ground, whereas a reserve defines what is presently economically recoverable with current technology (Figure 3).

3.1 RANKING CRITERIA

In order that the coal resources of the UK could be mapped, it was necessary to define a set of criteria that could be used to rank the resources suitable for exploitation by each of the various technologies. These criteria are described in the following section. All seam thicknesses quoted below are gross thicknesses, i.e. including any beds of siliciclastic sedimentary rock (dirt). Where two coal beds are separated by >0.3 m of dirt they have been treated as 2 separate seams.

3.1.1 Opencast Coal Mining

The area with technical potential for opencast working is defined as an area of coal- or lignite-bearing strata containing seams with <50 m non-coal-bearing overburden. It extends to depths of 200 m below the ground surface, the normal limit of opencast workings in the UK. It excludes a small area of non-coal bearing strata at the base of the Coal Measures. These areas are independent of the current land use. In most instances these coincide with the area of outcrop of coal-bearing strata, although there will not necessarily be an exact match, e.g. areas with a thick coverage of superficial deposits such as drift will be discounted. In reality, areas with potential for opencast mining must satisfy a very wide-ranging set of geological, engineering and planning constraints that cannot be described or discussed within the scope of this report. The remaining resources potentially suitable for opencast coal mining have not been calculated as part of this study, but resource areas have been defined and mapped.

3.1.2 Underground Coal Mining

Areas with the technical potential for underground coal mining are defined here as unmined areas where coal seams >1.5 m thick are present between depths of 200 and 1200 m. However, in reality, areas with potential for underground mining must satisfy a very wide-ranging set of geological and engineering constraints that cannot be described or discussed within the scope of this report. Consequently, only the major underground mining prospects identified by British Coal in their Plan 2000 exploration phase have been identified on the maps (Moses 1981). Some of these are identified in the DTI Review of Prospects for Coal Production in England, Scotland and Wales carried out by International Mining Consultants (IMC) in March 1999. There is no implication that these areas are suitable for underground mining. The remaining resources potentially suitable for underground coal mining have not been calculated as part of this study, but resource areas have been defined and mapped. In terms of existing mines, a good summary of the remaining reserves is available in the DTI Reports ‘Review of the Selby Complex’ (IMC 2002a) and ‘A Review of the Remaining Reserves at Deep Mines for the Department of Trade and Industry’ (IMC 2002b).

3.1.3 Coal Mine Methane (CMM)

Methane trapped in coal and surrounding strata can be released as a result of mining; this gas is known as Coal Mine Methane (CMM). The resource is the volume of gas in coal and surrounding strata (gas-in-place) that will be released by longwall extraction over the remaining life of the mine (Creedy et al 2001a). This gas is released not only from the mined seam, but also from seams in the collapsed and fractured, and thus de-stressed, strata surrounding the mined seam. Longwall mining may de-stress strata from 160-200 m above and 40-70 m below the worked seam (Creedy et al 2001a). This methane is an underground safety hazard so the control of this methane, by dilution with air, has been carried out for hundreds of years, but it is only recently that the methane has been systematically captured and utilised. When mining ceases, the residual gas contained in these strata forms an abandoned mine methane (AMM) resource.

A CMM resource area is defined as the mining licence around a working mine with methane drainage. CMM resources have not been calculated as part of this study, but resource areas have been defined and mapped. CMM sites are identified by a shaft location for the working mine and the potential area of CMM extraction is represented by the mine licence.

3.1.4 Abandoned Mine Methane (AMM)

Abandoned Mine Methane (AMM) consists of the fuel gas (mainly methane) fraction of the free gas trapped within abandoned coal mines, plus any methane that can be desorbed from the coal seams in the strata surrounding the mined seam by applying suction to the mine workings (Creedy et al 2001a). There are approximately 1,000 abandoned coal mines in this country. Mines which worked coal seams that initially contained $<1m^3$/tonne coalbed gas commonly emit mixtures of carbon dioxide and de-oxygenated air referred to as blackdamp. These mines are unsuitable for AMM production.

A resource area is best defined as the extent of underground longwall or other 'total extraction' workings not submerged by recovering or recovered mine water levels. However, it is beyond the scope of this project to accurately distinguish total extraction workings from other workings. Furthermore, the volume of workings not submerged by recovered or recovering mine water is only poorly known. For the purposes of the project, the resource areas are defined as consisting of those workings outside the area of opencast potential in which mine water levels are recovering rather than recovered. This intentionally excludes the shallowest workings, which are least likely to have been worked by longwall methods.

In this report, criteria used to identify an AMM resource are as follows:

- Recovering rather than recovered groundwater levels in abandoned mine workings
- Initial seam gas content known or considered likely to be >1m^3/tonne of coal, although seams with less than about 3 m^3/tonne methane are not likely to be significant AMM prospects
- Shallow workings, i.e. those in the zone of potential for opencast mining, excluded (to reduce major air ingress)
- Seams <150 m above the mined seam(s) and <40 m below the mined seam(s) comprise the resource base

Clearly, there is a window of opportunity for AMM exploitation that will close when groundwater levels in abandoned mines have fully recovered.

AMM resources have not been calculated, but resource areas have been defined and mapped. Four areas are marked on the maps, namely:

- *Good prospects for abandoned mine methane (AMM) (Mine workings not recovered)*. In these areas methane values are known to be >1m^3/tonne and the mine waters in these workings are thought to have not recovered. This is due either to mine water control by pumping or to the recent closure of a mine. Mine water recovery reports produced for the Coal Authority were kindly made available for inspection by this study. Notes taken from these and other reports and publications were used to construct areas where mine water levels are thought to be mainly recovered, recovering or unverifiable. Note that the areas constructed on the maps are an interpretation made by the authors of this report and do not necessarily bear any relation whatsoever to the views of the Coal Authority or its agents or subcontractors. Furthermore the mine water recovery will change through time.
- *Variable AMM prospects (Mine water recovering or conditions not known)*. In these areas methane values are known to be >1m^3/tonne and the mine waters in these workings are thought to be in a state of recovery. Variable prospects also occur where the state of the mine water recovery is unknown, but the mines were abandoned fairly recently.
- *Poor AMM prospects (Mine waters probably fully recovered or initial seam gas content <1m^3/tonne*. In these areas methane values are known to be either <1m^3/tonne, or the mine waters in these workings are thought to be fully recovered. These areas tend to be characterised by old workings that were abandoned 40 years or more ago.
- *AMM prospects unverifiable*. In these areas there is no information to substantiate the level of the mine water recovery.

When using the maps it should be borne in mind that the levels of mine water in underground workings are poorly known or unknown in significant areas within the UK coalfields and so these areas are far from definitive. Resources may occur outside the area of recovering mine waters and conversely there are likely to be flooded workings within the area of recovering mine waters. Furthermore, the recovered areas will increase in size with time at the expense of the recovering areas.

3.1.5 Coalbed Methane from Virgin Seams (VCBM)

Coalbed methane is the methane-rich gas found naturally within coal seams. Typically it consists of 80-95% methane, 0-8% ethane, 0-4% propane and higher hydrocarbons, 2-8% nitrogen and 0.2-6% carbon dioxide, together with traces of argon, helium and hydrogen (Creedy 1991). In mines it can be explosive when mixed with air. It is known as firedamp in the mining industry.

Coalbed methane originates from the coalification of organic matter during its burial. Organic matter accumulates at the ground surface as peat. As it becomes progressively more deeply buried beneath other sediments, it gets progressively hotter and is subject to greater pressure. It is compressed and heated and transformed first into lignite and then bituminous coal and finally, if coalification proceeds far enough, into anthracite. During this transformation volatile matter is driven off. However, a proportion of the methane is retained in the coal. This process occurs extremely slowly, over geological timescales, often taking millions of years. Coalification may stop at any stage of the process if the progressive heating and compression of the coal (usually by progressive burial) stops.

The criteria used to define and map the location of VCBM resources are as follows:

- Coal seams greater than 0.4 m in thickness at depths >200 m
- Maximum depth of 1200 m
- Seam gas content >1m^3/tonne
- 500 metres or more horizontal separation from underground coal workings
- Vertical separation of 150m above and 40 m below a previously worked seam
- Vertical separation of >100 m from major aquifers, and
- Vertical separation of >100 m from major unconformities
- Areas with a CMM resource (current underground coal mining licences) were excluded.

Note that the presence of a CBM resource does not imply permeability in the coal seams or that the resource can be recovered economically now or at any time in the future.

Following application of the criteria as established above, regions with potential for CBM were derived. In order to refine these CBM regions and produce a more accurate resource calculation these regions were divided into smaller areas across which the methane values are believed to be fairly consistent. These areas were defined using methane point and contoured data, available in Creedy (1986, 1988, 1991) and Wardell Armstrong (2002). These areas were then marked on the maps and labelled consecutively as CBM Areas 1, 2, 3 etc. The resource density, which represents the CBM resource as a function of its area, was used to rank the CBM areas, with CBM area 1 on each map representing the area with the highest resource density.

3.1.6 Underground Coal Gasification (UCG)

Underground coal gasification (UCG) describes the process by which various combinations of air, oxygen, hydrogen and steam are injected into one or more *in-situ* coal seams to initiate partial combustion. The process generally involves the drilling of at least 2 boreholes, one to act as the gasifier and one to collect the product gases. The injectant reacts with the coal, which produces heat and drives off gases (hydrogen, carbon monoxide and methane), which are subsequently recovered through a production well. The basic chemical processes and the calorific value (CV) of the gas produced are similar to conventional industrial gasification processes, although the final gas composition is somewhat different. Compared to CBM, UCG generally produces a gas of medium CV with a heating value of about 30% that of CBM. If air, rather than oxygen, is used as a partial oxidant then a lower CV product gas is produced with a heating value of about 10% that of CBM. The other difference is that with UCG typically 75% of the energy value of the affected coal is produced as useful energy at surface, whereas with CBM it much lower.

The main criteria used for the delineation and mapping of resource areas with potential for UCG were:

- Seams of 2 m thickness or greater
- Seams at depths between 600 and 1200 m from the surface
- 500 m or more horizontal and vertical separation from underground coal workings and current coal mining licences
- Greater than 100 m vertical separation from major aquifers, and
- Greater than 100 m vertical separation from major overlying unconformities

Underground coal gasification can take place either under shallow, low pressure conditions or at depth, under high pressure. The latest UCG projects all try to work close to the hydrostatic pressure to minimise pollution spread, and so shallow schemes (100-200m) like Chinchilla operate closer to atmospheric pressure (~10 bar) than those at greater depth such as the European trial (~60 bar). Shallow operations have lower drilling costs but the disadvantage is the potential for environmental pollution and a lower CV gas. High pressure encourages methane production and cavity growth.

For this generic study, a minimum depth of 600m has been assumed to lessen the environmental impact at surface, in terms of hydrogeology, subsidence and gas escape. **This does not rule out shallow UCG for specific sites in the UK, where the local strata and hydrogeological conditions can support operations in seams closer to the surface than 600m**. The 1200m depth represents the normal limit for mining in the UK, and the same figure was used for UCG on the basis of drilling costs and working pressure at surface. More work might establish that UCG can go deeper, and there are advantages in terms of energy produced in doing so.

A seam thickness of 2m or greater has been chosen for economic reasons – greater thickness means more coal for gasification. It has also been suggested in the European studies that UCG reactions in thin seams are not generally sustainable, although the Soviets have reported that seams down to 1m in thickness can be gasified.

Other factors that are important in any UCG scheme, but were not used in the mapping process were:

- Impermeable layers of strata surrounding the target coal seam
- Seam bedding dip between 5° and 30°
- Absence of any major faults in the area
- Low values for sulphur content, ash content and swelling index
- Environmental and hydrogeological conditions
- Proximity to users
- Licence conditions that might be imposed by Regulatory and Planning Authorities

To define UCG areas the borehole database was interrogated to identify boreholes which contained coals in excess of 2 m in thickness at depths between 600 and 1200 m from surface. The 600 and 1200 m lines, drawn on each map, mark the lower and upper limits of each UCG resource area. It can be seen from Figure 4 that the maximum possible resource area is defined where the 600m line intersects the top of the coal-bearing strata and the 1200 m line intersects the base of the coal-bearing strata. Coal seams that met these criteria, but were less than 100 m below the base of the Permian, were excluded. Boreholes that met the criteria were plotted on a base map together with the extent of underground workings and existing mining licences. The resource area could then be defined. Three resource subdivisions could be identified: good, unverifiable and poor. These are represented on the maps as different colours zones. Good areas meet the criteria as defined above. Unverifiable areas represent regions where the UCG potential is unknown. This may be related either to the absence of borehole data, or to the lack of deep penetrating boreholes (i.e. >600m) within an area. Poor zones represent areas where coals are present at the required depths, but do not meet the thickness criteria.

3.1.7 Carbon Dioxide Sequestration

Because carbon dioxide (CO_2) sequestration requires that CO_2 remains in place for very long time periods, areas of coal suitable for mining or underground gasification are not suitable for CO_2 sequestration. Areas considered to contain coal resources potentially suitable for CO_2 sequestration by adsorption onto coal fall into two categories:

- Areas of unminable coal seams (defined on the maps by areas where coal seams are at depths >1200 m and >500 m from mine workings), and
- Areas where coal seams are at depths of <1200 m, but CO_2 sequestration might take place in association with underground coal gasification or coalbed methane production

The former are regarded as primary areas for CO_2 sequestration and are identified on the maps. The latter are regarded as secondary opportunities and are not marked on the maps. Because this is an immature technology, no implication as to the methodology for CO_2 sequestration is made. Figure 4 indicates that this area is at a maximum if it is defined at the position where the 1200 m line cuts the base of the coal-bearing strata. This also creates an overlap zone between the area suitable for UCG and that of the potential CO_2 sequestration area. Hence the position where the 1200 m line intersects the base of the coal-bearing strata is marked on the maps.

The main area that might prove suitable for CO_2 sequestration are those areas of unminable coal seams at depths >1200 m (on the base of the Coal Measures). Contours on the base of the Coal Measures were taken from the 1999 BGS/CA Coal Resources Map of Britain. These contours are relative to ordnance datum (OD) and hence needed to be corrected so that they were relative to ground level. Ground level data from the Centre for Ecology and Hydrology (CEH) Digital Terrain Model (DTM) were used to correct the OD based contours and the derived dataset was recontoured using a 500 m grid spacing, with 100m contour interval. The 1200 m contour line was then extracted and shown on the new technologies maps.

3.2 RISK AND UNCERTAINTY

There are a number of geological factors that are important for the coal technologies and can have an impact on the exploitation of the resources; these can be viewed as risks. Many of these are described by Creedy et al. (2001). There are also areas of uncertainty regarding the accuracy of the resource assessment and mapping process. These are detailed in the following sections.

3.2.1 Risks

The main geological risks for the non-mining technologies are summarised below:

3.2.1.1 Coal Mine Methane

- Mine closes prematurely, although the methane then becomes an AMM resource
- Methane contents are low and methane is not routinely or efficiently captured by the working mine
- Variable supply and quality of methane due to mining and geological reasons

3.2.1.2 Abandoned Mine Methane

- Inadequate methane quality and quantity
- The level and rate of groundwater recovery reducing the accessible volume of connected mine workings
- Air ingress into workings associated with inadequate sealing of mine entries
- Difficulties establishing a good connection between unflooded mine workings and the surface via boreholes/shafts/drifts

3.2.1.3 Virgin Coalbed Methane

- Heavy faulting
- Low seam permeability
- Variable or low gas content

- Unpredictable gas pressure/saturationWater disposal at surface

3.2.1.4 Underground Coal Gasification

- Heavy faulting
- Overburden composition and potential leakage of produced gases/by-products into aquifers
- Groundwater quenching the reaction
- Subsidence
- Seam thickness variability
- Coal conditions inductive to lateral cavity growth
- Fugitive emissions or migration of potentially harmful combustion products

3.2.1.5 Carbon Dioxide Sequestration

- Poorly defined concept
- Low seam permeability
- Seam matrix swelling as a result of CO_2 injection
- Fugitive methane emissions
- Fugitive CO_2 emissions
- Heavy faulting
- Future attempts to recover energy value from coal
- Mobilisation of potentially harmful chemical species due to Ph shift cause by CO_2 dissolution in water

3.2.2 Key uncertainties

There are areas of uncertainty regarding both the resource delineation and the mapping process. Some of the major areas of uncertainty relate to such factors as data availability, data reliability, project resourcing, the presence of faulting and hydrogeology.

Data availability is a major factor when it comes to defining the resource area and for calculating total coal thickness that meet the criteria for a particular technology. Data availability can relate to the presence or absence of a borehole in an area of interest, or to the depth of penetration (=total depth or TD) of a particular borehole. The BGS digital database of borehole locations (see the BGS Geoscience Data Index on http://www.bgs.ac.uk/geoindex/home.html) lists approximately 8238 boreholes >200 m and 2760 boreholes >600 m that lie on the coalfields, or their subsurface extensions. Approximately 1504 boreholes were analysed and databased for this project (see Section 4.1). This represents a small fraction of the total number of boreholes available, but databasing of boreholes was limited by the size of the project budget and the project timescale. It is clear that more data is available that could contribute to further detailed studies.

Data reliability is another area of uncertainty and is difficult to assess. The main problem will lie with boreholes; features such as sidewall caving and faulting are key issues. Old boreholes are less reliable in terms of accurate depths, quality of core descriptions and core recovery. Drilling technology has improved considerably in the last few decades and hence are more likely to be reliable. For these reasons this study selected the most recent boreholes where available.

The presence or absence of faults is an important issue and can have an impact on the development of the new resources. For UCG in particular identification of a suitably sized, unfaulted block is a pre-requisite. However, the identification of all faults that affect the UK Coal Measures is a significant study in itself and is beyond the scope of this project. Major faults are shown on the new technologies maps, but the more numerous small scale faults have not been identified. BGS maps show the positions of faults at surface, however, faults present in coal-bearing strata in the subsurface, especially where buried below younger strata would need to be identified and mapped using seismic reflection data. This is a major undertaking that would need to form the focus of a separate study.

Within the Coal Measures there are numerous minor aquifers (Jones et al. 2000) and the overlying Permo-Triassic sandstones form important major aquifers (Allen et al. 1997). The major aquifers have been taken into account whilst carrying out this project, with a vertical stand-off distance of 100 m applied to the definition of UCG and CBM resources. However, minor aquifers are known to occur within the coal-bearing successions studied, interbedded with coals, and might have an impact on resource exploitation, e.g. water rich sandstones could quench a UCG reaction. Site specific borehole studies will be able to identify such minor aquifers.

Some of the resource specific areas of uncertainty are discussed below.

3.2.2.1 Coal Mine Methane

The key limitation on the definition of the CMM resource area is the assumption that the mining licence defines the resource area. This assumes that all seams will be extracted across this area, which is generally not the case. A more accurate assessment could be derived from using the data made available by IMC (2002a & b), which provide sufficient details on the planned extent of workings for each seam.

3.2.2.2 Abandoned Mine Methane

There is significant uncertainty associated with the definition of AMM resource areas due to the lack of detailed knowledge regarding the state of mine water recovery in the coalfields. Mapped areas need to be treated with caution and detailed studies undertaken to prove the presence of a resource.

3.2.2.3 Virgin Coalbed Methane

The main uncertainties relating to the mapping of VCBM resources are the limited amount of seam gas content data and the borehole availability.

3.2.2.4 Underground Coal Gasification

As discussed above (Section 3.2.2) it is clear that borehole availability plays a major factor in the determination of UCG resources and uncertainty exists as to whether all resources have been identified. In order to minimise this risk, boreholes were selected at regularly spaced intervals where possible. Where resources were identified further boreholes were selected to try and produce the best possible definition of the resource area. In the deeper parts of coalfield this was not always possible due to restrictions on borehole availability. Uncertainty also exists regarding continuity of seams between boreholes related to, for example, faulting. Only detailed site specific studies can address these issues.

3.2.2.5 Carbon Dioxide Sequestration

This area has been defined using the 1200 m contour (on the base of the Coal Measures), taken from the 1999 BGS/CA Coal Resources Map of Britain. As described in Section 3.1.7, the OD based contour line was corrected so that it was relative to ground level. The main uncertainties involved here include the possibility that the contour was not accurately defined initially, together with the inherent way in which the new contour was derived.

4 DATASETS USED IN THE STUDY

4.1 BOREHOLE DATABASE

In order to determine whether coal seams meet the criteria for the new technologies a digital database of coal seam data was compiled. Borehole information from the BGS National Geosciences Data Centre was used for this study. This incorporates the former British Coal records collection, which was also used. Most boreholes were drilled as coal exploration boreholes by British Coal and its predecessors. However, many of these do not penetrate to depths in excess of 600 m or so, restricting the resource evaluation at greater depths. Deeper boreholes are typically hydrocarbon exploration wells and coal seam presence and thickness have to be interpreted from geophysical logs and drill cuttings.

Borehole information was available in the form of written and graphic logs. A digital dataset was created by entering the information into an Excel spreadsheet. Approximately 1500 boreholes were analysed and databased (see Appendix - Table A1). Data recorded included the borehole name, grid reference, surface elevation and drilled total depth (TD), unique borehole reference indicator, depth to the top and base of every coal seam, thickness, coal seam name, together with any other relevant feature mentioned in the borehole logs, such as base of the Permian, base of Coal Measures and position of main marine bands. These data are not reproduced in this report, but the basic metadata related to each borehole is given in Appendix Table A1. Depths were entered in metres as downhole values relative to surface elevation. It should be stressed that the compiled borehole dataset used does not represent a complete set of all boreholes available for each coalfield. The selection of boreholes was subjective, although where possible a regular spacing of the deepest boreholes was chosen, to ensure a good spacing of data points. Given the project constraints, it is believed that this database represents a good sample of the available boreholes.

4.2 MINE PLAN DATA

Digital mine plan data was used to identify areas of past and present underground and opencast mining and the location of existing mining licences, i.e. the areas within which permission has been granted to extract coal. In England, Scotland and Wales these data were supplied by The Coal Authority (CA). This includes data up until May 2002, when the data was supplied. Additional mining subsequent to this date is not shown on the maps. Data were available for all the onshore and nearshore area, up to approximately 1 km from the coast. Areas further offshore were not available and hence are not represented on the maps provided by this study.

Mine plan data for Northern Ireland were supplied by the Geological Survey of Northern Ireland, a branch of the Department of Enterprise, Trade and Investment (Northern Ireland)

4.3 DATASETS DERIVED FROM 1999 BGS/CA COAL RESOURCES MAP OF BRITAIN

A number of the mapped features are derived from the 1999 BGS/CA Coal Resources Map of Britain, including both the 'at surface' and 'concealed' areas of lignite and coal-bearing strata, the area with theoretical potential for opencast workings and the main faults that cut the base of the coal-bearing strata.

4.4 OTHER DATASETS

Other datasets that were used in this study include:

- BGS 1:50,000 digital geological map data (DigMap 50K)
- Digital dataset of onshore petroleum exploration (PEDL and EXL) licences, supplied by the DTI Oil and Gas Directorate
- Seam gas content data originally obtained by British Coal and provided by Wardell Armstrong
- Locations of shafts or abandoned mine and working mine locations compiled as part of this project

4.4.1 Petroleum licence areas

The Petroleum licences shown on each new technologies map were supplied by the DTI. The DTI website (http://www.og.dti.gov.uk/upstream/licensing/lictype.htm) gives definitions of the different types of petroleum licences. Prior to 1996, DTI issued a sequence of separate licences for each stage of an onshore field's life: an Exploration Licence (EXL or XL), an Appraisal Licence (AL), a Development Licence (DL) and a Production Licence (PL). Petroleum Exploration and Development Licences (PEDLs) were introduced at the Eighth Licensing Round to reduce the bureaucracy associated with issuing this series of Licences. Hence DTI no longer issues these older licences, but a number of them are still in force. When one of the few remaining EXLs reaches its expiry date it can be converted to PEDL terms.

A further type of licence is the Methane Drainage Licence (MDL), which can be granted to a mine to permit the capture of methane given off during working at a coal mine. Technically, capturing the drained methane requires a Licence under the Petroleum Act 1998, but mines can be granted an MDL to improve underground safety. MDLs generally cover much smaller areas than PEDLs (usually the size of the mine), and can overlap geographically with one or more PEDLs.

5 MAP PRODUCTION

The main product of this study is a series of maps that illustrate the resource areas for conventional and new technologies. Maps were drawn using ESRI®ArcMap™ (v.8.3) GIS software. Due to the complexity of the information to be displayed, it was decided to produce two types of maps for each area of the country, one illustrating the mining technologies and the other type illustrating the new technologies. In total 21 of each type of map were produced, at 1:100,000 scale. The areas covered by these maps are illustrated in Figure 5. These are available in both paper format and as a Adobe Acrobat pdf file supplied with this report. In addition to this, a montage or summary map was produced. This comprises two main maps at 1:1,750,000 scale and inset maps, at 1:600,000 scale, showing more detail.

5.1 MINING TECHNOLOGIES MAP

This aim of the mining technologies map is to illustrate the potential resource areas for the conventional mining based technologies, including CMM and AMM, as well as the areas that have previously undergone opencast and underground mining.

Each map, at 1:100,000 scale, comprises a header text box displaying the title of the map. Another text box immediately below contains general project details and a copyright and liability statement. On each map there is a minimum of 2 further text boxes, one with generic text describing the technologies covered by the map and one or more map specific text boxes, describing the features of the mining technologies unique to the map. Each map illustrates the following features:

- *Urban areas*. Most, but not all of these urban areas are named. The source of these data is the digital chart of the World (DCW), Edition 1, July 1992.
- *Coastline.*
- *Borehole locations selected for current study*. These represent the positions of the boreholes which were databased as part of this study. As discussed previously, this is not necessarily a complete set of boreholes that are available.
- *Large working coal mines*. This is represented as a single point, marking the position of one of the shafts of each of the main large working coal mines.
- *Shafts of abandoned coal mines*. A database of abandoned coal mines was created and marked on the maps. This is by no means a comprehensive list, but most of the mines that were in existence post nationalisation (1947) are shown. For each mine, only the position of one shaft is marked on the map.
- *Lignite at surface*. The extent of outcrop of the main lignite-bearing stratigraphic units is marked on the maps.

- *Coal-bearing strata at surface*. This represents the area where coal-bearing strata could be expected to be present at the surface. In most instances the coal-bearing strata will be buried below a thin covering of more recent superficial deposits such as drift or alluvium. There is no differentiation between the different ages of the coal-bearing strata on these maps.
- *Concealed coal-bearing strata <1200 m from surface datum*. This represents the area where coal-bearing strata are present in the subsurface at depths less than 1200 m, buried below younger strata. The downdip limit is the 1200 m line, drawn on the top of the coal-bearing unit (Figure 4). This area has potential for further underground mines, as long as suitable geology is present. In most instances the cover rocks immediately overlying the coal-bearing strata are Permo-Triassic in age, although in Kent the Permo-Triassic is absent and the Coal Measures are overlain by younger Mesozoic strata. In South Wales, the majority of the Coal Measures are not concealed below younger strata, so the presence of coal-bearing strata is represented by the 'Coal-bearing strata at surface' pattern. It should be borne in mind that coal-bearing strata in this coalfield do continue to depths in excess of 1200 m, but they are not concealed.
- *Concealed coal-bearing strata >1200 m from surface datum*. This represents the area where coal-bearing strata are present in the subsurface at depths in excess of 1200 m, buried below younger strata. The updip limit is the 1200 m line, drawn on the top of the coal-bearing unit (Figure 4). The downdip limit is the known extent of coal-bearing strata.
- *Present Opencast Licences*. This represents the bounding area within which a licence has been granted to work coal using opencast techniques. This was supplied as a digital dataset by the Coal Authority in May 2002. Any subsequent changes to this date are not shown on these maps.
- *Past opencast workings*. This represents the site boundary of former opencast workings, as represented by the licence area. It does not mark the actual position of the working areas within a site. The Coal Authority supplied this as a digital dataset in May 2002. Any subsequent changes to this date are not shown on these maps.
- *Area with theoretical potential for opencast workings*. The source of this dataset is the Coal Resource Map of Great Britain (BGS/Coal Authority 1999). The potential areas suitable for opencast mining may not exactly match the area of outcrop of coal-bearing strata in a number of coalfields, i.e. the area suitable for opencast mining may be smaller. This may be due to a number of geological factors. Firstly it may be known that there are no seams in a particular area, secondly seams may be too thin and discontinuous to be worked and thirdly the thickness of superficial deposits (e.g. drift) may be too great. In places drift thickness can exceed 50 m, which limits the potential for opencast mining. This is particularly the case in parts of the Burnley, Cheadle, Shrewsbury and South Lancashire coalfields.
- *Underground mining licences*. This represents the bounding area within which a licence has been granted to work coal underground. The Coal Authority supplied this as a digital dataset in May 2002. Any licence changes subsequent to this date are not shown on these maps.
- *Extent of underground workings with 500 m buffer zone*. The extent of former underground mine workings was supplied as a digital dataset by the Coal Authority. The data were supplied as comma separated variable (CSV) format files (ASCII xyz data), with each file representing the workings of one named seam. This was loaded into the ESRI®ArcMap™ (v.8.3) GIS software and a 500 m buffer zone was added to this dataset. The buffer zone represents a stand-off distance recommended to mitigate against the possible interaction of former mine workings with the other technologies. Permission to publish these data in this format was kindly granted by the Coal Authority.
- *Underground mining exploration prospects*. During the 1970's and 80's exploration by the former British Coal-National Coal Board identified a number of underground mining

exploration prospects which were considered to represent the most promising areas for future underground mines. These are represented as generalised areas on the maps.

- *Extraction sites for coal mine methane (CMM) from licenced working mines*. These represent the known locations where CMM is currently being utilised. They are identified by a shaft location for the working mine.
- *Resource area for CMM*. As defined in section 3.1.3, the CMM resource area is defined as the mining licence around a working mine with methane drainage. Hence they were derived from the Coal Authority digital licence dataset, supplied in May 2002. Any licence changes subsequent to this date are not shown on these maps.
- *Good prospects for abandoned mine methane (AMM) (Mine workings not recovered)*. In these areas methane values are known to be >1m^3/tonne and the mine waters in these workings are thought to have not recovered.
- *Variable AMM prospects (Mine water recovering or conditions not known)*. In these areas methane values are known to be >1m^3/tonne and the mine waters in these workings are thought to be in a state of recovery. Variable prospects also occur where the state of the mine water recovery is unknown but the mines were abandoned fairly recently.
- *Poor AMM prospects (Mine waters probably fully recovered or initial seam gas content <1m^3/tonne*. In these areas methane values are known to be either <1m^3/tonne or the mine waters in these workings are thought to be fully recovered. These areas tend to be characterised by old workings that were abandoned 40 years or more ago.
- *AMM prospects unverifiable*. In these areas there is no information to substantiate the level of the mine water recovery.

In terms of the AMM lines, it should be stressed that the good, variable, poor and unverifiable areas are all generalised as it is not possible to accurately define these areas. In a number of areas, e.g. on maps 2 and 14, where it is known that the workings have fully recovered, single lines are drawn around all the workings, rather than individual lines around every small set of isolated underground workings.

5.2 NEW TECHNOLOGIES MAP

The new technologies maps give the potential resource areas for the new technologies of UCG and VCBM. They also identify any areas where coal is present below 1200 m for possible CO_2 sequestration in un-minable coal seams. Each map, at 1:100,000 scale, comprises a header text box displaying the title of the map. Another text box immediately below contains general project details and a copyright and liability statement. On each map there is a minimum of 2 further text boxes, one with generic text describing the technologies covered by the map and one or more map specific text boxes, describing the features of the new technologies unique to the map. The areas covered by these maps are illustrated in Figure 5. Each map illustrates the following features:

- *Urban areas*. Most, but not all of these urban areas are named.
- *Coastline.*
- *Borehole locations selected for current study*.
- *Fault at base of coal-bearing strata*. This dataset is derived from the 1999 Coal Resources Map of Great Britain and marks the positions where faults cut the base of any coal-bearing strata.

- *Petroleum licences*. This was supplied by the DTI in May 2002. Any changes to the licences subsequent to this data are not shown.
- *Underground mining licences*. The Coal Authority supplied this as a digital dataset in May 2002. Any licence changes subsequent to this date are not shown on these maps. These are important to mark on the new technologies map, as the potential for UCG and VCBM is restricted to areas outside the existing mining licences.
- *Lignite at surface*. This is described in Section 5.1.
- *Coal bearing strata at surface*. This is described in Section 5.1.
- *Concealed coal-bearing strata <1200 m from surface datum*. This is generally only shown on the maps in areas of concealed coal-bearing strata down to depths of 600 m. Areas between 600 – 1200 m are represented as UCG areas. The exceptions are where existing mining licences occur; here the UCG potential is not shown.
- *Concealed coal-bearing strata >1200 m from surface datum*. This is described in Section 5.1.
- *Area with good UCG potential*. This represents an area that meets all the criteria for UCG, as outlined in section 3.1.5.
- *Area with poor UCG potential*. This represents an area that does not meet all the criteria for UCG, specifically seams are present at suitable depths, but do no meet the required thickness of >2 m.
- *Area with unverifiable UCG potential*. This represents an area in which coal is believed to be present at suitable depths, but borehole information is lacking. Hence the potential cannot be verified. Unverifiable areas require further investigation to determine their resource potential.
- *CBM boreholes*. The positions of known CBM boreholes as of May 2002 are marked on the maps. These data are supplied from the DTI (see the Basic Onshore Well Data Excel file at http://www.og.dti.gov.uk/upstream/licensing/onshore_10th/basic_onshore.htm)
- *CBM resource areas*. The criteria used to define CBM resource areas are given in section 3.1.6. Definition of the resources is described in section 10.3.1.
- *Areas greater than 1200m from surface datum with potential for CO_2 sequestration*. Areas where coal is present below 1200 m have been distinguished on the maps as coal resource areas which may have theoretical potential for CO_2 sequestration. Areas where CO_2 sequestration might be considered in conjunction with UCG or VCBM are not shown on the maps.

5.3 MONTAGE MAP

The montage map is a summary of all the mining and new technologies. This comprises two main maps of the UK at 1:1,750,000 scale and inset maps at 1:600,000 scale showing more detail of selected coalfield areas. The mining montage map and insets show the past and present exploitation, and potential, of the UK coal resources for opencast and underground mining, abandoned mine methane (AMM) and coal mine methane (CMM). The new technologies montage map and insets show the potential UK coal resources for the new exploitation technologies of underground coal gasification, coalbed methane and CO_2 storage. Descriptions of these technologies are given in separate inset boxes.

6 OPENCAST COAL MINING

It is beyond the scope of this report to give a detailed account of opencast coal mining. An opencast mine, as opposed to an underground mine, works coal from open pits directly analogous to quarries. Overburden rocks and unconsolidated superficial deposits are removed from above a coal seam and the coal seam itself is then removed. Shallow underground workings are commonly encountered in UK opencast coal pits. The maximum depth of UK opencast coal pits is approximately 200 m and up to 50 m of overburden may be removed from above the first seam.

There are numerous advantages of opencast mining, particularly the low cost, the temporary nature of the workings, improvements in the land following site restoration and the flexibility of the mining operations. For example this allows thin seams (>0.15 m) and old pillar and stall workings to be mined, as well as coping with faulted ground. There are environmental issues associated with opencast coal mining, mainly relating to noise, dust, visual impact and transport of the coal. Consequently opencast coal mining is severely constrained by planning requirements in and around urban and amenity areas.

As at April 2002 there were 56 opencast sites in production (source DTI web site: www.dti.gov.uk/energy/inform/site_installations/ dukes2_10.pdf). Production from opencast mines in 2001-02 was 14.47 million tonnes (source: Coal Authority Annual Report 2002). It is not possible to provide a generalised statement on which coalfields are more favourable than others as the viability of an opencast mine is extremely site specific, requiring detailed drilling across the area of interest. However, it is clear that some coalfields, e.g. Forest of Dean, Pembrokeshire, are least suited because much of these coalfields lie within National and Royal Parks. The larger coalfields offer more scope to find areas suitable for opencast sites.

7 UNDERGROUND COAL MINING

It is also beyond the scope of this report to give a detailed account of underground coal mining but detailed information on all working mines is provided by IMC (2002). Currently there are 13 large underground coal mines in the UK and 1 smaller anthracite mine (Table 1). The large deep mines all use longwall mining techniques, with retreat faces common, although Ellington also has some pillar and stall workings (IMC 2002). One advantage of retreat mining is that the geology is proven in the gate roadways prior to setting out the face. UK deep mined coal is generally produced at considerable depths and has to compete with opencast coal or cheaper underground mined coal available on world markets. There has been a rapid and drastic decline in the number of deep underground mines. In 2001, total UK production was 32.1 million tonnes, with 17.3 million tonnes from deep-mined production. This study has shown that there are large areas still remaining that would be geologically suitable for underground mining. Analysis of the data indicates that of the c.40,000 km^2 of onshore coal-bearing strata, approx 10,700 km^2 lies at depths >1200 m so will not be suitable for underground mining. Subtracting all areas where previous mining has taken place (approximately 12,900 km^2) leaves an area of approximately 16,400 km^2, which represents the area with theoretical potential for future underground mining. This is a general calculation and does not assume that coals of sufficient thickness for mining will be present across this area. **COAL MINE METHANE (FROM WORKING MINES)**

The US EPA (1998) recognise three types of CMM:

- Fumigant or ventilation air methane (VAM), which represents a dilute mixture of methane (typically < 1% of volume) in air that is vented to the surface as part of the mine ventilation system,
- High grade CMM obtained by draining in advance of mining (not practised or feasible in the UK) that may be suitable for injection into natural gas pipelines (After treatment to remove water and excess carbon dioxide), and
- Goaf gas, which represents the mixture of methane and air in the goaf. This is usually less than 85% methane (typically 35-75% in the UK) so is not suitable for direct pipeline injection but can be used for power generation (or direct use).

The latter two can be used as a fuel source. Even ventilation air methane CMM can make a contribution; for example the CMM power station at Appin Colliery in New South Wales incorporated the feeding of a proportion of the methane-bearing vented mine air to the gas engine intakes (Creedy et al. 2001a).

There has been a long history of mine gas utilisation in the UK (Young et al. 1994). Current CMM drainage, capture and utilisation technologies are described by Creedy et al. (2001a) and the mines in which there is current CMM capture and utilisation are summarised in Table 2. The Selby mines (Riccall/Whitemoor and Stillingfleet/N Selby) have been identified for closure.

Thus all major working mines except Daw Mill and Ellington already drain methane, so there is little scope for increasing the amount of methane drained. However, Creedy et al. (2001a) indicated that utilisation of CMM is potentially feasible at all deep mines with methane drainage, so there may be scope for increasing utilisation of the resource. There may also be scope for increasing the proportion of gas captured and used at mines with existing gas drainage systems. There is also an environmental case for utilisation, as methane is an important greenhouse gas, with a Global Warming Potential (GWP) 23 times more powerful than carbon dioxide on a mass basis over a 100 year timespan (Ramaswamy et al. 2001).

The total UK CMM resource was calculated by Creedy et al. (2001a) to be 1,620 x 10^6 m^3.

9 ABANDONED MINE METHANE

9.1 PRINCIPLES AND PRACTICE

9.1.1 Principle of AMM production

The principle of AMM production is that total extraction methods of coal mining (e.g. longwall mining) lead to the collapse of overlying and underlying strata into the void from which the coal seam is extracted. This reduces the stress regime of the seams in a zone up to about 150-200 m above and 40-70 m below the mined seam, fractures the intervening strata and increases the permeability of the coal (Creedy et al 2001a). Whilst the reduction in pressure associated with exhausting mine ventilation results in some of the methane desorbing from these seams and mixing with the mine air, some is retained. A further reduction in pressure, caused by applying suction to the workings, causes more methane to desorb from the surrounding seams into the workings.

Gas cannot be extracted from flooded workings, so the state of mine water recovery is critical to the success of projects (Creedy et al 2001a).

9.1.2 Criteria for successful AMM projects

Creedy et al (2001a) point out that the main requirements for a successful AMM project are:

- An extensive area of interconnected workings
- A large de-stressed coal volume
- Significant residual methane in the de-stressed unmined seams
- Unfilled shaft or drift from which the gas can be extracted
- No connections to shallow outcrop workings so no air ingress
- Local market for gas

9.2 AMM RESOURCES IN THE UK

9.2.1 Resource area mapping

It has been estimated that anything between 20,000 (Coal Authority) and 300,000 (Association of Coal Mine Methane Operators) tonnes of methane is seeping from abandoned mines every year. Theoretically, much of this methane could be captured by AMM projects and utilised. Creedy et al. (2001) suggest an AMM resource of 213 x 10^9 m^3, of which 107 x 10^9 m^3 is potentially recoverable.

In order to obtain an accurate AMM resource figure would require a detailed analysis of the mine plan dataset and boreholes. Factors that would need to be considered include the volume of coal removed by mining (=coal reservoir volume), the volume of coal in which the permeability has been enhanced by mining, the seam gas content, as well as a detailed understanding of the mine water recovery per mine. This is beyond the scope of this project. Hence AMM resources have not been calculated but resource areas have been defined and mapped. As defined in Section 3.1.4, four areas are marked on the maps, namely:

- *Good prospects for abandoned mine methane (AMM) (Mine workings not recovered)*
- *Variable AMM prospects (Mine water recovering or conditions not known)*
- *Poor AMM prospects (Mine waters probably fully recovered or initial seam gas content <1m³/tonne*
- *AMM prospects unverifiable*

The areas represented on the mining maps that have good, variable and unverifiable AMM prospects are listed in Table 3. Reference needs to be made to the mining technologies maps in order to identify the areas indicated in the table. All coalfields, or parts of coalfields, not mentioned in the table can be considered as having poor AMM prospects; their areas were not calculated. In these coalfields, the mines are known to have closed many years ago, pumping has ceased and mine waters are largely thought to have fully recovered. The good, variable and unverifiable areas represent highly generalised, broad regions across which there may be AMM potential and it should be emphasised that detailed studies need to be carried out even within potentially good AMM areas in order to clearly identify AMM prospects. The reasons for this are that these area were largely defined with respect to the likely state of the groundwater recovery and take no account of other important factors such as the mining method employed, the depth of mining, age of mining, and potential closure of mine roadways.

9.2.2 AMM resource exploitation in the UK

AMM exploitation is not a new concept; there has been a long history of AMM production in Belgium, France and Germany (Smith 1992). In the UK AMM extraction has been recorded onwards from at least 1954, when the National Coal Board collected methane for electricity generation from the closed Old Boston colliery (Sage 2001). Between 1957 and 1967 gas was recovered at a rate of 187.2 m^3/hr (52 l/s) before increasing up to 1,080 m^3/hr (300 l/s) (Sage 2001). More recently several companies have launched projects in the UK, with varying long term success:

Octagon Energy recently developed a 5.5 MWe (five 1.35 MWe) electricity production plant using AMM from Hickleton colliery, near Barnsley in South Yorkshire. Gas is extracted from the shaft.

Octagon Gas, a 50% subsidiary of Octagon Energy, uses AMM from Silverdale colliery to supply a local industrial customer and a 10 MWe power station. Here gas with a calorific value of 98% methane equivalent is being recovered at rates up to 1,400 m^3/hr, representing approximately 8,000 tonnes of methane per year (Sage 2001). The gas is utilised for burner tip use and electrical generation.

Alkane Energy developed a series of Green Energy Parks based on AMM. They hold acreage in the UK covering 5,590 km^2, which include over 300 abandoned coal mines. Former and active AMM sites include:

- Shirebrook, 5 miles north of Mansfield. AMM extracted from the former colliery drift fuels a 9 MWe (five 1.8 MWe) on-site power station used for electricity generation. Gas production to June 2000 totalled approximately 9 million m^3 with a production rate of about 3,500 m^3/hr, and a methane concentration of 70 % (Sage 2001). However, recent problems such as water and air leaking into the gas extraction pipe means that production is running at about 50 % of its original output (Alkane Energy 2003).

- Markham, east of Chesterfield. AMM is produced from one of the former colliery shafts and supplies gas for industrial heat applications at Coalite Chemicals and Coal Smokeless Fuels plant. Production during 2000 was reported as running at an annual rate of 6,500 m^3, with a methane concentration of 45% (Sage 2001). However, recently, operational difficulties have been reported, although remediation has resulted in an increase in gas quality (Alkane Energy 2003).

- Steetley. AMM from Steetley Colliery workings fed a 3 MWe power station just west of Workshop, Nottinghamshire. The Steetley site drew gas for 4.5 days per week at rates of up to 1,250 m^3 per hour (Sage 2001). Gas production to June 2000 totalled 6.5 million m^3 (Sage 2002). Due to operational difficulties and poor economics this site ceased production in December 2002 (Alkane Energy 2003).

- Wheldale, near Castleford, Yorkshire. Gas is supplied to Scottish & Southern Energy. In 2002 output was at 80% of total capacity and was below expectations (Alkane Energy 2003).
- Barnsley (Monk Bretton), West Yorkshire. CMM is sold to Rexam Glass for process heat. Restricted flows have been reported and a new borehole is required to rectify this problem (Alkane Energy 2003).
- Pipework is currently being installed in the drift of the former Prince of Wales Colliery in order to extract the AMM. It is planned to use the methane to generate electricity, which will be fed into the national network.

However, Alkane have recently suspended development of further AMM sites in the UK because falling electricity prices and the failure of AMM to qualify as Renewable Energy have meant that their electricity generating operations are no longer financially viable.

In January 2002 StrataGas completed the commissioning of the Bentinck AMM gas plant from the closed drift of the old Annesley Bentinck mine complex near Kirkby-in-Ashfield, Nottinghamshire. The plant is designed to be able to pump up to 3,300 m^3 per hour of gas and is used for electricity generation in three 3.5 MW_e spark-ignition engines, owned by Warwick Energy Limited. Warwick Energy are contracted to take up to 38 million therms of gas from StrataGas over the next five to seven years.

10 COALBED METHANE

10.1 PRINCIPLES AND PRACTICE

10.1.1 Internal structure of coal

Coal contains a natural network of vertical or subvertical fractures known as the cleat. The dominant set of fractures (the face cleat) crosscuts the subordinate set (the butt or back cleat). When combined with the natural bedding planes in coal, they divide the coal seam in 3 planes and, where well developed, allow it to break up into small 'bricks' (Figure 6).

The cleat generally imparts some permeability to the coal (in bituminous coals commonly 1 millidarcy or less but rarely up to about 30 millidarcies). However, this is not always the case; sometimes the cleat can be filled with any of a variety of mineral cements. Where permeability is high enough, gases and water can penetrate the cleat and the gases can diffuse out from the solid coal into the cleat. Because the face cleat is longer than butt cleat permeability is commonly anisotropic and is greater in the face cleat direction. Cleat intensity, defined as the number of fractures per unit distance perpendicular to the cleat, is therefore an important factor in determining permeability (MacCarthy et al. 1996).

Coal is a highly porous substance. However, the porosity consists to all intents and purposes entirely of micropores that are too small for fluids to flow into. The exchange of gases between the cleat system and the microporosity in the solid coal is thought to occur by diffusion. The total internal surface area of the micropores is about 20-200 $m^2 g^{-1}$ coal (Patching 1970). Therefore, the retention of large amounts of gas molecules in a small volume of coal is possible. Methane molecules are adsorbed on the internal surfaces of microfractures and pores as a monomolecular layer. They also occur as free gas molecules in the cleat and any other cracks and fissures. The proportion of the free gas in the total gas content of coal is about 5-10%. Normally, the free gas and the adsorbed gas phases are in equilibrium in a coal pore and there is a constant and equal exchange of molecules between them. The adsorbed gas is held in place by electrostatic forces. Reducing the pressure on the coal or increasing its temperature can overcome these forces.

10.1.2 Virgin coalbed methane production

In coalbed methane production, a well is drilled into the coal seam and pumped to lower the pressure in the seam. This allows methane to desorb from the internal surfaces of the coal and diffuse into the cleat, where it is able to flow, either as free gas or dissolved in water, towards the production well. Vertical wells are commonly used. However, CDX Gas LLC is currently conducting a horizontal drilling project at the Pinnacle Mine in West Virginia, USA. where they have drained anywhere from 640 acres to 1100 acres from one drill site. This patented technology costs approximately twice that of traditional vertical drilling technology. However, there may be savings from draining more gas from less well heads and therefore spending far less on infrastructure. It is claimed this technology works most efficiently in areas of low permeability and actually increases underground pressures enabling up to 85% recovery of gas in place (compared to anywhere from 15% to 65% recovery rates that are reported by vertical drillers).

Permeability (imparted mainly by the cleat) is necessary to achieve virgin coalbed methane production. The permeability of coal seams is low, so coalbed methane wells are normally stimulated to improve connectivity between the borehole and the cleat system. The coal seams may be hydrofractured, or they may be cavitated. Hydrofracturing is the method of well stimulation used to date in the UK (for details of the well completion and stimulation as carried out at the Airth coalbed methane project, Scotland, see Bacon, 1995). Cavitation, the process of excavating a part of the seam around the borehole, improves connectivity to the cleat system and also allows the coal to expand slightly into the cavity, locally improving the permeability of the coal. Cavitation has not been tried in the UK.

Also important is the orientation and magnitude of the *in situ* stress, and laboratory studies show that coal permeability decreases with increasing stress (Durucan & Edwards 1986). In the UK the horizontal stress is not unusually high (Evans 1987), so it is likely that increasing effective (or overburden) stress with depth will the most important control on the decrease in permeability (MacCarthy et al. 1996).

10.2 PROSPECTS FOR VCBM IN THE UK

Previous studies of the coalbed methane potential of the UK coalfields include Ayers et al. (1993), Glover et al. (1993a, 1993b), MacCarthy et al. (1996), Creedy (1999) and Creedy et al. (2001a).

10.2.1 Resource base

A sound resource base, ideally consisting of a few thick permeable coal seams with high gas content (>7 m^3/tonne) is required for successful VCBM development. In the mainland UK, the potential resource commonly consists of seams mostly 1-2 m thick and seldom exceeding 3 m in thickness. In this respect it is similar to that found in the CBM-productive Black Warrior Basin in the USA (Hewitt, 1984), where a typical well in the Cedar Cove development is a multi-seam completion with a total of 7.6 m of medium to low volatile bituminous coal (Hobbs et al., 1993). Kuuskraa and Boyer (1993) indicate that most successful production in the Black Warrior Basin comes from coals with methane content >7 m^3/tonne and resource densities >1 million m^3/ha.

The gas content of UK seams has been measured in the major coalfields (Creedy 1983, 1986, 1988, 1991) and the average thickness of coal in seams >0.4 m thick and resource density have been calculated. Table 4 shows the results of CBM resource density estimates for the CBM areas considered in this report. The ash content of coals is an important factor in CBM, because high ash contents effectively reduce the storage capacity of coal seams (MacCarthy et al. 1996). The measured mean methane content in many Scottish coalfields is based on samples from Westphalian or Upper Limestone Formation coals whereas the principal target for CBM is the Limestone Coal Formation. Furthermore, many of the measurements in Scottish coalfields are from coalface samples and in some cases there may have been greater degassing prior to analysis than estimated. Thus the published mean methane content analyses may not be representative of the virgin CBM values in the Limestone Coal Formation coals in certain Scottish coalfields. This is supported by analysis of the mean methane content the Limestone Coal Formation in the Airth boreholes in the Clackmannan coalfield where seam gas content is reported to be in the range 8-10 m^3/tonne (Creedy 1999).

The CBM resources and resource densities were calculated for the areas that meet the criteria using the following equations:

CBM Resource ($10^6 m^3$) = Area (m^2) x *Clean coal thickness (m) x Average methane value (m^3/tonne) x Average coal density (g/cm^3)

*clean coal thickness = total thickness of coal meeting the criteria minus 15% ash & dirt allowance

CBM Resource Density ($10^6 m^3 ha^{-1}$) = (CBM resource ($10^6 m^3$) / Area (m^2)) / 100

The total CBM resource in the UK is calculated to be 2,900 x 10^9 m^3. This compares well with a previous estimate of 2,450 x 10^9 m^3 (Creedy 1999). Given annual UK natural gas consumption of approximately 100 x 10^9 m^3/year, it corresponds to about 29 years consumption.

The part of this resource that realistically could be exploited in the near future is very much smaller. The resource base in coalfields where the resource density exceeds 1 x 10^6 m^3 ha^{-1} and mean seam gas content is >7.0 m^3/tonne is a little less than 1 x 10^{12} m^3 (Table 5). It is highly unlikely that more than 3% of this could be recovered, because of perceived widespread low seam permeability, planning constraints, etc. Therefore it seems unlikely that the recoverable part of the resource will exceed 30 x 10^9 m^3, equivalent to four months UK gas supply.

10.2.2 Exploration and production in the UK

To date there has been a relatively low level of virgin coalbed methane exploration drilling in the UK. Table 6 shows the wells drilled:

There has been some gas production at Airth (see: http://www.envoi.co.uk/P22CBMsyn.pdf). Gas production was initially high, although this has reduced and is now not thought to occur at commercial rates. Methane dissolved in the formation waters is known to occur in the Midland Valley of Scotland and it is a possibility that this might have been the case at Airth, with the initial high rates representing production that included methane from saturated groundwaters. Further study is required to investigate this possibility.

10.2.3 Economic rates of gas production in the UK

In the USA a small producing well may produce 1,400 m^3/day (50,000 ft^3/day) and a large producer over 142,000 m^3/day (5 million ft^3/day). A theoretical analysis of UK market conditions indicated that for a 30 well field average well flows of 5,600 – 7,000 m^3/day may be needed for commercial viability (Creedy 1999). To date there is little evidence that such flows can be produced from UK coals because of their apparently low permeability.

10.2.4 Permeability of UK coal seams

The permeability of the Great Row seam in North Staffordshire was estimated to be of the order of 0.1-0.5 millidarcies (Creedy 1999). This is the only published permeability estimate for unfractured UK coal seams. Hughes & Logan (1990) indicate that the minimum permeability needed to recover methane is generally >1 mD.

Too little *in situ* testing has been undertaken in the UK to provide firm representative permeability data (Creedy 1999). Indirect evidence gathered from many years of mining operations strongly suggests that permeability in the Carboniferous coal seams of the UK is generally low. For example, most coal seams in deep underground mines in the UK are dry and do not transmit water. Significant flows of gas have not been reported from any coalbed methane exploration wells in the UK apart from those in the Namurian Limestone Coal Formation at Airth, Scotland. There, permeabilities measured after fracturing and cleanup of the coal seams were reportedly up to 25 mD (Creedy 1999). Because these permeabilities were measured after fracturing and cleanup, there is always the possibility that the fractures may penetrate overlying and underlying (permeable) strata, as has been reported from the USA (Steidl 1993).

For comparison, significant production has been established from Carboniferous coal seams in the Black Warrior Basin (Alabama, USA) where permeability is 2-30 mD.

10.2.5 Gas flow rates from UK coal seams

Methane flow rates measured in in-seam boreholes in UK coal mines are generally around 0.1 m^3 per day per metre of borehole length. Flows of up to 30 m^3/day per metre have been recorded in Staffordshire, but these are thought to be associated with seams de-stressed by adjacent workings. However, borehole flows as high as 62 m^3/day per metre length have been encountered in virgin conditions in the former Point of Ayr Colliery, North Wales (Creedy 1999). Significant gas flow rates have also been measured in boreholes associated with mining operations at the former Solway Colliery, Cumbria (Dunmore 1969). Suction was applied to these boreholes.

With the exception of these two collieries, methane flows from virgin seams in UK coal mines appear to be typically one or two orders of magnitude lower than those encountered in the mines of Alabama, where coalbed methane production has been established in the Black Warrior Basin (Creedy, 1999).

10.2.6 Gas saturation in UK coal seams

Coal *in situ* normally contains enough methane to saturate its microporosity (the surplus having been driven off during coalification). In saturated coals, the amounts of methane found are dependent on temperature, pressure, rank (degree of coalification) and to some extent on the composition of the coal (Creedy 1991). However, if the coal has been uplifted and subsequently reburied it may be undersaturated with respect to coalbed methane. In many parts of the UK, the major coal seams are undersaturated with methane with respect to their present depth (Creedy 1988, 1991). The principal effect of undersaturation is that the pressure in the seam has to be reduced to below the level where the seam is saturated with gas before gas will desorb from the seam.

10.2.7 Gas pressure within UK coal seams

Gas pressure in UK coals commonly ranges from negligible to 1.5 MPa (Creedy 1991). The gas pressure in UK coal seams is commonly less than one fifth of the hydrostatic pressure that would be expected at the relevant depth, the one notable exception being in Point of Ayr colliery, North Wales, where pressures approaching hydrostatic were encountered (Creedy 1991). Therefore the coal seams, or the surrounding strata that enclose them, must have very low permeability because they are not connected to the hydrostatic pressure regime found in overlying strata.

10.2.8 Potential economies of scale

Costs and revenues differ, but experience from the USA suggests that centralised water and gas treatment facilities serving 30 wells or more can lead to savings of one order of magnitude over costs at individual wells. The critical size for a near-market operation (where central facilities and infrastructure can be shared) is 100 wells or 1.5 million m^3/day of gas (Kuuskraa & Boyer 1993). These kinds of economies of scale may be difficult to achieve in the UK.

11 UNDERGROUND COAL GASIFICATION

11.1 INTRODUCTION

As described earlier, UCG is the process by which steam and air or oxygen is injected into a coal seam via a surface injector well. These injected gases react with the coal to produce a combustible gas that is collected at the surface via a producing well (Creedy et al. 2001). Methane is a product of pyrolysis and gasification and its formation is favoured under high pressures. As part of the gasification process a cavity develops as the coal burns. Wilks (1983) predicted that the cavity that develops around the injection well would be pear-shaped, assuming that the reaction processes were uniformly distributed around the reactor and that the roof collapses immediately into the cavity formed by gasification (Creedy et al 2001). If the roof does not collapse the cavity will grow in size and some of the fluid reactant will by-pass the coal and the reactor efficiency will decline. This results in an O_2 rich product gas or a rise in the product temperature (Creedy et al. 2001). Hence in the UK, the UCG process is aided at depths greater than 500m by the high in situ stresses that characterise the UK Coal Measures which should ensure caving and thus reduce the possibility of by-passing (Creedy et al 2001).

There are three main forms of UCG. The first involves drilling a series of vertical boreholes, gasifying the coals and relying on a combination of high pressure air fracing (pulses of air to open the cleats in the coal) and the natural permeability of the coals to extract the gas. This type of UCG generally takes place at shallow depths. An example of this is the Chinchilla project in Australia (Walker et al. 2001; Blinderman & Jones 2002). The low permeability of most UK coal is thought to preclude this method, although there may be exceptions in some coal structures. The second type of UCG takes place in existing or abandoned coal mines (eg Liuzhuang Mine, China). In this process mined galleries are sealed off, air is injected into these galleries, the surrounding coal is gasifed and the gaseous products piped up a shaft or borehole to the surface. The European and later US trials have involved the gasification of coals in which the production and injection wells are connected by in-seam drilling techniques. UCG is a cost effective means of extracting energy from coal because it avoids the high costs associated with mining and constructing a surface gasifier (typically hundreds of million pounds) and leaves ash and dirt underground. The recent technological achievements in UCG have been addressed by Creedy et al. (2001b) and reference should be made to this report for details.

There are some significant environmental issues of the UCG process, including the potential for subsidence, atmospheric emissions, the possible interactions of the UCG cavities with aquifers and the potential for pollutants to migrate away from the cavity (Creedy et al. 2001b). Careful site selection and process control are required to control the dispersal of gas and liquid by-products from the gasification cavity, and the configuration must be designed and assesses to minimise ground subsidence. Abatement equipment at surface is used to maintain air emissions (acid gases, particulates and heavy metals) within the Regulatory requirements.

Interest in UCG in the UK has developed as a result of the DTI Energy Paper 67 (1999), which identified UCG as one of the potential future technologies to develop the UK coal resource. Energy Paper 67 produced a number of technical and economic goals for UCG including:

- Improve the accuracy of in-seam drilling to achieve a 400 m run in a 2 m seam, on a consistent basis
- Examine the implications of burning the gas produced in the Spanish UGE trial in a gas turbine
- Produce an estimate of the landward reserves of coal, which could be technically suitable for UCG. In the first instance, this could be coal seams at least 2 m thick and at a depth not exceeding 1200 m
- Identify a site for a semi-commercial trial of UCG. This would require a block of coal about 600 m by 600 m, and a seam thickness of at least 2 m
- Identify the parameters that UCG would have to meet if it were to be competitive with current North Sea gas production costs
- Carry out a pre-feasibility study for the exploitation of UCG offshore in the southern North Sea

An initial pre-feasibility study was commissioned by the DTI and further studies have followed, such as a geological and site evaluation study (IMC 2001), drilling and a review of the technological advancements (Creedy et al. 2001b). Economic and public perception studies are currently being carried out.

11.1.1 History of UCG

There have probably been over fifty or so different UCG trials and larger schemes operated during the past 50 years or so. Early UCG trials usually took place at shallow depths (<200m); for example the Newman Spinney trial in the UK in 1959 was drilled to the Fox Earth Coal at a depth of 75m (Gibb & Partners 1964). These trials were generally of short time periods (1-2 months). The exception to this were the large-scale, air-blown schemes in Russia and Uzbekistan and a test at Chinchilla in Queensland, Australia, which was initiated by Linc Energy in December 1999 and was mothballed in 2003. The Russian and Australian schemes used simple technology and produced a low calorific value gas. China has considerable experience of UCG, with 16 trials completed since 1990. Feasibility studies have also been carried out in Canada, India, Pakistan, Russia, Slovenia and Ukraine, and a small burn was conducted in New Zealand in the early 1990's.

Underground coal gasification has been carried out in Kuzbass, Siberia, at the Yuzhno-Abinskaya gasification plant since 1955. This involves the gasification of bituminous coal, 1.3 - 3.9m thick, producing a low calorific value gas used for heating (Walker 1999). The reprocessing volume achieved 2 million tons that constituted about 4 billion m^3 of gas.

The Angren Coalfield is the largest coal deposit in Uzbekistan, containing about 1.8 billion tons of mostly brown coal (lignite) that is used as fuel for Uzbekistan's power generation. The Angren mine also has underground coal gasification technology in place since 1955 to produce gas for the Angren power station. The lignite seam varies in thickness from 4-20m and lies at depths of between 130-350m. The output in 1963 was believed to be about $860 \times 10^8 m^3$, but present production is about half of the 1963 figure (Walker 1999).

There was much research carried out in the 1970s, and a number of trials went ahead. The Thulin scheme, in Belgium ran from 1978 to 1986 and gasified a thin seam at a depth of 1000m. In the US, UCG research has focused on relatively shallow (100m deep) coal seams and tests were focused on the development of the process itself. However, the Rocky Mountain 1 (RM1) UGC test at Hanna, Wyoming, involved extensive site characterization, instrumentation and monitoring in order to gain a detailed understanding of the environmental and hydrogeological variables (Boysen et al. 1990; Creedy et al. 2001). Commercial projects were evaluated (eg at Rawlins, Wyoming), but the low cost of gas in the early 1990's prevented these projects from being viable.

The El Tremedal European trial in Spain (1993-1998) confirmed the technical feasibility of UCG at depths between 500-700 m and has shown that improved deviated drilling techniques in deep seams can provide interconnected channels suitable for use in underground coal gasification (Green 1999). In this trial a controlled retraction injection point (CRIP) system was used to control the gasification procedure (Green 1999).

The IGCC project in Chinchilla, Australia began development in 1999, and was the first project to propose the use of UCG syngas directly in gas turbines (Blinderman & Jones 2002). The project involved construction of an underground gasifier and demonstration of the technology (Walker et al. 2001; Blinderman & Jones 2002). Approximately 32,000 tonnes of coal have been gasified, producing a low calorific value gas of about $5MJ/m^3$ at a pressure of 10barg (145psig) and temperature of 300°c (Blinderman & Jones 2002). Nine process wells have been producing gas from a 10m thick seam at a depth of about 140m (Blinderman & Jones 2002). Ground water monitoring has also been taking place in association with this trial and has revealed no contamination (Blinderman & Jones 2002). This is probably related to keeping the gasifier pressure less than the hydrostatic pressure of fluid in the coal seam and surrounding strata (Blinderman & Jones 2002).

UCG has been under review in the UK more or less since the early Newman Spinney trials in the 1950's. British Coal undertook major studies in the 1970's and 1980's and trial sites were identified in Nottinghamshire area towards the end of the 1980's as possible locations for the European trial – in the end the trial was located in Spain, as discussed above. The current UK programme was activated in 1999.

11.1.2 UCG resource calculation

The UCG resource was calculated using the areas that have been mapped as having good UCG potential, as defined in Section 3.1.5. Two volume calculations were performed. Firstly the minimum volume of coal available for gasification was calculated, using the equation below:

$$\textit{Min. vol. of coal suitable for gasification } (10^6 m^3) = \textit{'good' area } (m^2) \times 2\ (m)$$

This calculation was made assuming that the only minimum thickness of coal (i.e. a 2 m thick seam) was available for gasification across the area.

The second calculation involved taking an average of the total thickness of coal per borehole in the areas with good UCG potential and multiplying this average figure by the area of the good polygon.

$$\textit{Ave. vol. of coal suitable for gasification } (10^6 m^3) = \textit{'good' area } (m^2) \times \textit{average of the total thickness of coal per borehole that meet the criteria } (m)$$

It is difficult to determine accurate resource figures due to the limitations of the borehole dataset, particularly the fact that boreholes do not generally penetrate through the entire thickness of coal-bearing strata. In these instances it is not known whether there are coals present at greater depths that may meet the criteria. Although not truly accurate, this second calculation probably gives us a more typical idea of the volume of coal available for gasification than by applying a minimum value. The figures derived from these two calculations are given in Table 7.

The minimum total volume of coal suitable for UCG in the UK is nearly 5,700 x $10^6 m^3$ (~7 Btonnes), whereas the total volume of coal figure derived using the average coal thickness meeting the criteria per area is nearly 12,911 x $10^6 m^3$ (~17 Btonnes) (Table 7). This represents a resource of 289 years based on the current UK coal consumption of 58 Mtonnes per year.

12 CO_2 SEQUESTRATION IN ASSOCIATION WITH COAL

12.1 PRINCIPLES AND PRACTICE

12.1.1 Principles

Coal is a potentially attractive target for CO_2 sequestration, not only because of its ability to store CO_2, but also because the affinity of CO_2 to be adsorbed and retained onto coal is greater than that of methane (CH_4), so it can displace CH_4 from the sorption sites on coal. Injecting CO_2 into coal seams can enhance coalbed methane production. If so, some revenue might accrue that could help offset the costs of CO_2 sequestration.

Studies by Wolf et al. (1999) indicate that coal can hold approximately twice the volume of CO_2 as methane, although recent US studies have shown that some low rank coals (lignite and sub-bituminous) may adsorb from 6 to 18 times as much CO_2 as methane (Gluskoter et al. 2002). However, this varies with temperature and pressure and rank, amongst other factors. Once CO_2 is adsorbed onto coal it is not likely to migrate freely through the subsurface as if it were free CO_2 in a gaseous or supercritical phase. Thus there may be an intrinsic advantage in storing CO_2 in coal seams as opposed to in the pore spaces of conventional reservoir rocks. The adsorption of CO_2 sorption onto coal is a strongly exothermic (and thus possibly chemical) reaction that may be partly irreversible (Starzewski & Grillet 1989). Ongoing work is in progress at Strathclyde University (funded by BCURA) to further examine this exothermic reaction.

12.2 CARBON DIOXIDE SEQUESTRATION AS PART OF AN ENHANCED COALBED METHANE SCHEME

Enhanced Coal Bed Methane (ECBM) production coupled with CO_2 sequestration has been trialled at the Allison CBM unit in the San Juan Basin, USA by Burlington Resources (Stevens et al. 1998). The unit consisted of four injection wells, 16 producers, and one pressure observation well. During the project, which started in 1995, Burlington Resources injected over 57 million m^3 CO_2 into the [high permeability] Fruitland coal seams in the San Juan Basin with only limited CO_2 breakthrough. The objective was to stimulate coalbed methane production and recovery. For various operational reasons the trial could be considered to have been promising, but inconclusive in terms of enhancing CBM production. However, it is thought that it yielded 4.5 $x10^4$ m3 (1.6 Bcf) of enhanced gas recovery.

Nitrogen (N_2) can also be used to enhance CBM production. Injecting nitrogen into coal seams reduces the partial pressure of methane in the cleat and thus increases the rate of diffusion of methane from the coal into the cleat system, as well as flushing the gases from the cleat. This raises the possibility that flue gas could be used as an injectant for ECBM. If so, CO_2 separation at source might not be necessary and this would avoid the high costs associated with separating the CO_2. The Alberta Research Council (ARC) is leading a group of provincial, national and international organisations in a seven year project that started in 1997 and is researching the potential to enhance coalbed methane recovery factors and production rates by means of flue gas injection using a mixture of nitrogen and CO_2 (DTI 2001). The project aims to develop a multi-well pilot at a selected site in Alberta, Canada. It is commercially sensitive and only a few selected members of the consortium are taking part (DTI 2001). A further trial, the EU-funded Recopol project, started in November 2001 (Pagnier & Van Bergen 2002). It will represent the first European field demonstration of CO_2 sequestration in subsurface coal seams.

The Tiffany Unit in the San Juan Basin, operated by BP America, has been under intermittent nitrogen injection since 1997. It consists of 12 injection wells and 34 producers. Prior to injection gas production was 67.2-136.8 x 10^3 m^3/hr (100 to 200 thousand cubic feet per day (Mcfd) and this has increased to 6.8 x 10^5 m^3/hr (1000 Mcfd per day) during nitrogen injection.

12.2.1 Immaturity of ECBM technology

There are a number of reasons why ECBM is not yet a mature technology from the CO_2 sequestration perspective.

- CO_2 injection has not yet been demonstrated unequivocally to result in enhanced coalbed methane production.

- The methane held within coal accounts for only about >1 % of the total energy value of the coal. If the coal were subsequently mined or gasified *in situ*, any sequestered CO_2 would be released. As the CO_2 would probably have to be stored for hundreds of years before release, this would effectively sterilise the energy value of the solid coal for very long time periods, unless the carbon credit was repaid or the CO_2 was recaptured and stored elsewhere.

- CH_4 is a much more powerful greenhouse gas than CO_2. Hence it is extremely important to fully capture all fugitive methane emissions to ensure the process resulted in a net reduction in greenhouse warming potential.

- Swelling of the coal matrix as a result of CO_2 sorption could be an issue. It could reduce the permeability of the coal around the injection well such that injection could only proceed at uneconomic rates. Generally accepted principles dictate that adsorption/desorption of gas swells/shrinks the coal matrix; because permeability is directly proportional to the cube of the cleat width, a small increase/decrease in cleat width may significantly increase/decrease permeability (IEA 2002).

- When coal is hydrofractured to stimulate the production of coalbed methane, the hydrofracture commonly extends above of the seam as well as across the seam itself (Steidl 1993). If CO_2 were to be injected into fractured wells it is possible that it could leak into the strata surrounding the target coal seam. Alternatively it might become adsorbed onto surrounding seams, or it could find an alternative migration path and reach the ground surface or interact with the groundwater. The abundance of abandoned mines and boreholes in the coal-bearing strata in many areas of the UK suggests that there is a high potential for leakage of CO_2 or CH_4 from these strata in, or near, to abandoned mine workings. Consequently it is recommended that ECBM projects keep away from mine workings. Under high permeability conditions hydrofracturing of injection wells may not be necessary. In the Allison ECBM pilot project, CO_2 injection wells were not stimulated precisely in order to reduce the risk of CO_2 leakage outside the target coals (Stevens et al. 1998).

- Horizontal drilling technology as applied to ECBM is in its infancy

12.2.2 Coal and geological criteria for successful CO_2 sequestration in coal seams and CO_2-enhanced coalbed methane recovery projects

Stevens et al. (1998) suggest that the following geological and coal criteria are needed for a successful ECBM project:

- *Homogeneous reservoir*. The coal seams should be laterally continuous and vertically isolated from surrounding strata, ensuring efficient lateral sweep and containment of CO_2.
- *Simple structure.* The reservoir should be minimally folded and faulted. Closely spaced faults can compartmentalise the reservoir into isolated blocks or act as pathways for CO_2 leakage
- *Adequate permeability.* At least 1 to 5 millidarcies permeability is needed, primarily to allow flow of water through the reservoir. Given that most coal seams are much less permeable, finding adequate permeability will be a key exploration challenge.
- *Gas saturation.* Coal reservoirs that are saturated with respect to methane are economically preferred, although undersaturated coals can still be effective storage targets.
- *Depth.* Economic ECBM is likely to be limited to depths of roughly 300 to 1500 m, although sequestration may also be possible in somewhat deeper or shallower settings.
- *Coal geometry*. For engineering and well completion reasons, stratigraphically concentrated coal deposits (few thick seams) are preferred over dispersed settings (multiple thin seams).

12.3 CARBON DIOXIDE SEQUESTRATION IN ASSOCIATION WITH UCG

In certain circumstances the combination of UCG and CO_2 sequestration might be feasible and is an area of growing research interest. This is an attractive proposition because the process of UCG produces large quantities of CO_2 and there are major synergies between the two processes, e.g. advanced drilling, impermeable overlying strata, and the benefits of high pressure for CO_2 capture and injection. The process of gasification would result in the generation of large, highly porous cavities, which could be accessed by directional drilling or through the existing production boreholes. Carbon dioxide could then be injected at high pressure for storage and retention in the cavities. As the majority of the gas processing is carried out under high pressures anyway, there is little need for further recompression (Beath et al. 2000). Two different scenarios can be envisaged in which CO_2 might be sequestered:

- Injection of CO_2 into the cavity created by the UCG burn, and
- Injection of CO_2 into overlying coal seams destressed by the collapse of the roof of a UCG burn cavity. Clearly there will be scope for CO_2 to adsorb onto coal, however, little is known about the quantities of CO_2 that might be adsorbed onto coal at elevated temperatures and pressure such as might occur after a UCG burn, although due to the low thermal conductivity of coal this effect may not extend a significant distance into the seam.

If CO_2 were to be injected soon after the burn the high temperatures still present in the burn cavity would likely result in the CO_2 taking the form of a dense supercritical fluid. Supercritical CO_2 is highly reactive and an excellent solvent for hydrocarbons and other organic molecules and could dissolve various organics such as phenols and dioxins. At lower temperatures, following cooling, CO_2 could be stored as a free gas but, above 70 bar (~700 m), the gas would be in the dense phase.

An important issue associated with all forms of CO_2 sequestration is the degree of permanence of the process. Factors such as depth and stratal conditions, interaction with groundwater and induced discontinuities would form important considerations in this process and would require further investigation.

12.3.1 Criteria adopted to identify areas with potential for CO_2 sequestration

The most important criterion was considered to be the need not to sterilise areas of coal as a potential future energy resource. As resources for both mining and UCG are limited to areas above 1200 m depth, the entire coal-bearing area >1200 m below ground level is considered to have potential, providing the necessary coal resources are present. These areas are identified on the New Technologies maps. The major areas are in the centre of the Cheshire Basin (Map 10) and a large area of Lincolnshire and Yorkshire, bounded to the east by the coast roughly between Skegness and Bridlington (Maps 11 and 12).

Additionally, unminable or ungasifiable coal seams at depths of less than 1200 m may have potential to sequester CO_2 without sterilising a potential energy resource. Sequestration could occur either in CO_2-ECBM projects, or in association with UCG, or in some cases where there are very low methane saturation levels within the coal, without methane displacement and capture. Areas where such sequestration could take place have not been marked on the maps because not enough is known about the potential technology to identify them.

MAP DETAILS

The following sections discuss the resource maps that form the main deliverables of this project. The commentary should be read in conjunction with the maps, which are available in both paper and pdf form.

13 MINING MAP 1a (Bovey Tracey)

13.1 REVIEW OF LIGNITE IN THE AREA

The Bovey Formation is a succession of kaolinitic clays, sandy and silty clays, silts, sand and lignites of Cainozoic age, covering an area of approximately 31 km^2 (Map 1A). These strata occupy a partially fault-bounded trough termed the Bovey Basin, which extends for 11 km north-westwards from Newton Abbot (Selwood et al. 1984). It lies on the Sticklepath-Lustleigh Fault Zone and owes its origins to subsidence along this fault zone (Selwood et al. 1984). Estimates of the maximum thickness of the succession vary from 1066 to 1245 m, although only the upper 300 m have been proved (Selwood et al. 1984). The Formation is divisible into lower, middle and upper units, which are further divisible into a number of members. The major occurrence of lignite occurs in the Southacre Clay-and-Lignite Member (Middle Bovey Formation), which crops out between Newton Abbot and New Bridge (Selwood et al. 1984) (Figure 7). This member varies in thickness from 30 to 67 m. The lignite beds occur interstratified with brown clays and some silty clays and sands. Denistone borehole [8604 7422] proved 11.7 m of lignite, with some interbedded sediment, occurring between the depths of 20.4 and 32.9m (Selwood et al. 1984). The Heathfield Borehole proved 79.6 m of clay and lignite beneath 59.4m of upper Bovey Formation sands and clays; lignite beds up to 10.5 m thick were recorded (Selwood et al. 1984). The Bovey Tracey No. 4 Borehole proved lignite and clay between 22.2 and 60.6 m, with lignite forming 43% (16.4 m) of the succession, in beds from 0.2 – 2.3 m thick. The use of lignite as a fuel began in the early 18th century. Blue Waters Mine closed prior to 1875. There are also records of workings pre First World War, although mining ceased between 1914 and 1945. The calorific value of the lignite varied from 18.4 MJ/kg (7907 Btu/lb) and 26.4 MJ/kg (11,340 Btu/lb) (Ussher et al. 1913).

13.2 OPENCAST MINING

There has been quite extensive surface extraction of the Bovey Tracey lignite deposits, and a number of abandoned quarries are known in the area. The main commercial extraction was at the Blue Waters Mine, 1 km south of Bovey Tracey (Selwood et al. 1984). However, as far the authors know, it does not appear that there is a systematic surveying record of these and hence areas of lignite extraction are not shown on the map. There will be limited potential for further workings of these lignites.

13.3 UNDERGROUND MINING

Lignites have not previously been worked underground in this area. The limited depths to which these lignites occur (typically <100m), together with the unconsolidated nature of the surrounding strata make these lignite deposits an unlikely target for underground mining.

13.4 Coal Mine Methane

These lignites have not been worked underground and hence do not form a coal mine methane resource.

13.5 Abandoned Mine Methane

There are no underground mines in this field and so no AMM resources are present.

14 NEW TECHNOLOGY MAP 1b (Bovey Tracey)

14.1 Coalbed Methane

There are no seam gas content measurements for the Bovey Tracey lignite field but it is assumed that methane contents are very low because of the low rank. It is highly unlikely that the Bovey Tracey lignite field has any VCBM potential.

14.2 Underground Coal Gasification

Beds of lignite up to 11 m thick occur in the Bovey Tracey area but they occur at depths up to about 70 m, i.e. above the minimum depth of 600 m required as part of the criteria. Hence none of the Bovey Tracey lignite deposits meet the requirements for UCG so there is no resource available.

14.3 Carbon dioxide Sequestration

The limited depths to which the Bovey Tracey lignites occur in the subsurface means it is highly unlikely that they would be suitable for carbon dioxide sequestration.

15 MINING MAP 2a (Kent)

15.1 Review of coal in the area

The Kent Coalfield is the most southerly coalfield in the UK. Coals were first discovered at the foot of Shakespeare Cliff, Dover in 1882, following trial borings for a possible Channel Tunnel. In 1896, the Shakespeare Colliery was opened but problems, including flooding, meant that it closed in 1914 without producing coal. Collieries which actually produced coal included Snowdown, (opened 1912, closed 1986), Tilmanstone (opened 1913, closed 1985), Chislet (opened 1918, closed 1969), Stonehall, which started to produce until the workings flooded in 1914 and Betteshanger (opened 1927, closed 1989).

The coalfield comprises coal-bearing strata of Langsettian to Westphalian D age, although the main target coals occur in the Langsettian and Duckmantian (Lower and Middle Coal Measures). The Coal Measures are concealed beneath a cover of Mesozoic and Tertiary rocks and rest unconformably on Carboniferous Limestone. They are in excess of 750 m in thickness and 14 main seams have been recognised, with the youngest named Kent No.1 and the oldest, at the base, named Kent No.14 (Figure 8). The main worked coals were the Kent No.6 and 7, with the No.1 and 8 worked to a lesser extent. Coals generally occur at depths between 600 and 1500 m. The shallowest coals recorded in this study occur in the north (in the Littlebourne Borehole) where they are at depths in excess of 334 m. The deepest are in the Meggot Farm borehole, 6 km west of Dover, where they occur down to depths of 1315 m. The thickest coal recorded (?Kent No.14) is 2.95 m in the Swanton Court borehole, although there is at least 0.55 m of dirt associated with this seam. Coals are medium to high rank (Dines 1933; National Coal Board 1959). Seams in excess of 2 m include Kent No.8, 9 and 14, with No.4, 6, 9 and 11 in excess of 1.5 m in places. Measured methane contents in this coalfield are quite low with values of 2.3 m^3/tonne measured for the Kent No.6 Coal (Creedy 1986, 1988). Coal rank varies from very strongly caking (401) to non caking (201) and shows an overall decrease in an ESE direction.

The main structure within the coalfield is a south-easterly plunging syncline. The former Tilmanstone and Snowdown collieries lie along the axis of this structure, with the axis marking the thickest preservation of the Coal Measures. Hence, the north-eastern and south-western parts of the coalfield occur on the flanks of this structure and are more deeply eroded beneath the Mesozoic strata that unconformably overlie the Coal Measures. Faults typically trend north-west to south-east, with less common north-south faults. These are generally steeply inclined normal faults.

15.2 Opencast Coal Mining

The Coal Measures are present at depths generally in excess of 500 m, below a thick succession of Mesozoic and Tertiary rocks. Hence there is no opencast potential.

15.3 Underground Coal Mining

In this coalfield there were a number of shafts constructed, although coal was only worked in 4 collieries (Chislet, Betteshanger, Snowdown and Tilmanstone). There are now no working deep mines in the Kent Coalfield; the last mine, Betteshanger, closed in 1989. Large areas of this coalfield remain unmined and potential exists for future underground coal mining, particularly between Chislet and Betteshanger and also to the south of the old workings at Tilmanstone, where boreholes indicate thick coals are present (e.g. Kent No. 8, 2.23m in Swanton Court borehole), although they are typically at depths in excess of 900 m.

15.4 Coal Mine Methane

As there are no working mines in this coalfield there is no coal mine methane resource.

15.5 Abandoned Mine Methane

The underground workings in this coalfield associated with each mine are not connected and form distinct blocks. The last working mine in this coalfield, Betteshanger, closed in 1989, when pumping also ceased. It can be assumed that the mines have now flooded and have recovered to their natural level in the Chalk (Wardell Armstrong 2000a). Hence there are no AMM prospects.

16 NEW TECHNOLOGY MAP 2b (Kent)

16.1 COALBED METHANE

The criteria for VCBM are met across almost the entire coalfield, the exception being a narrow strip around its margins, where coals incrop against the Mesozoic and hence are not included in the resource. The average total thickness of coal suitable for VCBM is 11.6 m, although a greater thickness of coal is preserved in the centre of the main syncline. The coals are of low volatile bituminous rank and are friable, with closely spaced cleat and recurrent fusain bands. However, the low average measured seam gas content from coalface samples in the Kent No. 6 seam at Tilmanstone colliery (2.3 m^3/tonne; Creedy 1986, 1988) indicates that VCBM prospects are likely to be poor.

16.2 UNDERGROUND COAL GASIFICATION

Conditions suitable for UCG are only met in a narrow (10 x 6 km) north-east trending belt to the south-west of the former Tilmanstone Colliery workings. The volume of coal suitable for gasification is indicated in Table 7. Coals are present at the required depths in the northern and eastern parts of the coalfield, however, they are never more than 2 m in thickness and hence do not meet the criteria. The presence of a resource in the large areas that do not have borehole coverage could not be verified.

16.3 CARBON DIOXIDE SEQUESTRATION

Coal-bearing strata are present at depths in excess of 1200 m over a large area (c.183 km^2) of the southern part of this coalfield, between Tilmanstone Colliery and Dover, and this continues offshore. This forms an area potentially suitable for CO_2 sequestration. The low VCBM prospects of this coalfield make it an unattractive proposition for an enhanced CBM scheme associated with CO_2 sequestration. The region between the Westcourt Farm and Swanton Court boreholes forms an overlap zone between an area with good UCG prospects and the CO_2 sequestration area. This may have potential for a combined scheme involving CO_2 sequestration.

17 MINING MAP 3a (Western South Wales area)

17.1 REVIEW OF COAL IN THE AREA

The Pembrokeshire Coalfield, in western South Wales, covers an area of 130 km^2, stretching from Amroth in Carmarthen Bay in the east to Newgale, at the northern end of St Brides Bay, in the west. It actually comprises two small coalfields; the Little Haven to Amroth Coalfield, which trends roughly east-west and represents an extension to the main South Wales Coalfield to the east, and the smaller Nolton-Newgale Coalfield in the north-west.

Coal has been worked in this area for centuries, the earliest reference to coal mining being in 1324 in the neighbourhood of Saundersfoot. However, the seams are heavily faulted and folded, which made large scale mining difficult. Hence only a few mines were developed into large collieries. The last large mine (Hook) closed in 1948, with a small private working outlasting it by only a few years.

The Coal Measures succession in Pembrokeshire is thinner than, but generally similar to, that of the main South Wales Coalfield. However, it is very heavily faulted and folded. The main structures within the area are a series of WSW-ESE trending thrusts and faults, with associated folds (Glover et al. 1993).

The coals are all of anthracite grade and there is no seam methane content data available. The main coals are in the Lower and Middle Coal Measures. Eleven named seams are present, of which the most important are the Rock (of the Timber Vein group), the Timber and the Kilgetty (Figure 9). There is believed to be some Upper Coal Measures locally preserved in the Newgale and Picton Point areas, 6 km to the south east of Haverfordwest [200282 211766], but these contain only thin coals (Jenkins 1962). Coals are probably restricted to fairly shallow depths in this coalfield. Glover et al (1993) suggested that coals might reach a depth of up to 1000 m. However, there are no boreholes in excess of 310 m to support this statement.

Because of its structural complexity, the coalfield is poorly suited to UCG, CBM production and CO_2 sequestration.

17.2 Opencast Coal Mining

It is believed that coal has not been previously opencasted in this area, although areas technically amenable to opencast coal mining are present along the outcrop of the Coal Measures between Saundersfoot and Broad Haven and also at Newgale. However, a large part of the outcropping Coal Measures falls within the Pembrokeshire Coast National Park.

17.3 Underground Coal Mining

Coal was formerly worked underground in this area e.g. at Hook and Grove collieries, although the extent of coal workings is unknown and there are no workings shown on the mining map. The thickest seam is the Timber Vein, which, in Kilgetty borehole, is 1.8m in thickness, and at a depth of 45 m. The prospects for future mining are low, as the coalfield is structurally complex and the shallow seams are likely to have been worked.

17.4 Coal Mine Methane

There are no CMM resources in this area.

17.5 Abandoned Mine Methane

There are only minor shallow mine workings in the Pembrokeshire Coalfield. These are fairly old and likely to be flooded (Wardell Armstrong 2000b). AMM prospects are therefore considered to be poor.

18 NEW TECHNOLOGY MAP 3b (Western South Wales area)

18.1 COALBED METHANE

The Pembrokeshire Coalfield is strongly tectonically deformed and its detailed structure is poorly known. The coals are of anthracite rank but their gas content is not known. From the limited information available only one seam, the Kilgetty Vein, locally exceeds 0.4 m in thickness and is present at the required depths (i.e. >200 m). Thus there are no realistic CBM prospects and no resources have been calculated.

18.2 UNDERGROUND COAL GASIFICATION

Coals generally occur at shallow depths in the Pembrokeshire Coalfield and the deepest borehole reaches a depth of only 310 m below surface. Hence any UCG potential is unverifiable.

18.3 CARBON DIOXIDE SEQUESTRATION

There are no areas in this coalfield where coals are present at depths greater than 1200 m and this, combined with the very poor CBM and UCG prospects, indicates that the potential for CO_2 sequestration in this area is low.

19 MINING MAP 4a (South Wales)

19.1 REVIEW OF COAL IN THE AREA

The onshore South Wales Coalfield covers an area of approximately 2000 km^2. It is approximately 90 km in length along its east-west long axis and 27 km in width. A small (unmined) part of the coalfield lies in the near offshore, in Swansea Bay and Carmarthen Bay. In the latter the main coalfield joins up with the Pembrokeshire Coalfield. The central part of the coalfield forms a plateau up to 600 m above sea level that is criss-crossed by numerous north-east and south-east trending deep valleys. These are separated by upland moors and hills.

The coalfield has been extensively worked, particularly over the last two hundred years. Peak production, of approximately 57 million tons, was in 1913. Currently there are only 3 working mines in the South Wales Coalfield: Tower, Betws and Aberpergwm.

The geology of the coalfield has been summarised by Woodland & Evans (1964), Thomas (1974), Barclay (1989) and Glover et al. (1993). The Coal Measures are folded into a syncline such that the productive Lower and Middle Coal Measures crop out around the margins of the coalfield and the younger Upper Coal Measures crop out in the centre. The complete Coal Measures succession is up to about 2500 m in thickness. It is thickest in the western and south-western parts of the coalfield and is attenuated in the east (Ramsbottom et al. 1978).

The Coal Measures are divided into the Lower, Middle and Upper Coal Measures, of Langsettian (Westphalian A) to Westphalian D age. The succession of coal seams in the South Wales Coalfield is shown in Figure 10. The majority of the economically important seams occur within the Lower and Middle Coal Measures.

The Lower and Middle Coal Measures consist mainly of claystones and siltstones, with subordinate sandstones. These strata occur in units generally from 5-30 m in thickness, separated by coals that vary in thickness from traces to 4 m or more locally. In the Upper Coal Measures Pennant Sandstone Formation, sandstone becomes the dominant lithology, and only a few coals and mudstones are present.

Coal rank varies from high volatile bituminous in the south and east margins to anthracite in the north-west part of the coalfield (e.g. White 1991).

The coalfield is structurally complex. The major east-west trending syncline is asymmetric, with the southern limb being considerably steeper than the northern. Superimposed on this are several minor, broadly parallel east-west folds arranged en echelon, including the Pontypridd-Maesteg anticline, and the Llantwit-Caerphilly, Pengham, Gowerton and Llanelli synclines. Thrust faults, which normally strike NE-SW, are common (Gayer et al. 1991). Overviews of the structure of the coalfield are given by Owen and Weaver (1983) and Jones (1991).

The Coal Measures are deformed by both normal (extensional) faults and thrust (reverse) faults. The normal faults typically trend NNW-SSE whereas the thrust faults trend NE-SW and east-west. The Lower and Middle Coal Measures are known to be have suffered greater compressional deformation than the overlying Pennant Formation and coal seams are frequently duplicated by thrust repetition.

The Coal Measures rest conformably on Namurian Millstone Grit. They are at outcrop throughout the entire coalfield, except in a small area around Bridgend in the south where Triassic rocks locally overlie the Coal Measures.

19.2 OPENCAST COAL MINING

The South Wales Coalfield forms a broad east-west trending syncline, with the thickest coals, from the Lower and Middle Coal Measures, outcropping on the northern and southern sides of the syncline. Hence previous opencast sites have concentrated on the northern and southern sides of this syncline, although coals are present at shallow depth (i.e. <50 m) across the entire coalfield. Hence there are significant areas technically amenable to opencast coal mining still available in South Wales, the most favourable areas being on the northern and southern flanks. As of April 2002 there were 11 working opencast sites in this coalfield (source: DTI web site).

19.3 UNDERGROUND COAL MINING

Currently underground mining is limited to one large mine (Tower) and two small drift mines (Betws and Aberpergwm). Most of the central and eastern parts of the coalfield have been extensively mined and there are probably only limited resources in these areas. The area with the largest potential lies in the north-west, north of Pontarddulais and Llanelli, where relatively untouched coal is present across an area of approximately 70 km^2. Here a number of thick anthracite rank coals occur at depths up to 900 m. In the south the Margam prospect near Port Talbot has been extensively investigated and significant resources (27 million tonnes of coal) are believed to be present. A licence is in existence for this area, although mining has yet to take place.

19.4 COAL MINE METHANE

Methane has traditionally been a problem at Tower Colliery and prior to 1999 was vented to the atmosphere. However, in 1999 the colliery began to utilise the methane captured via the methane drainage system that was already installed. The methane is removed from the coal face by means of 30 m long boreholes drilled every 2-3 m at angles of 60° into the roof of the worked seam. The boreholes are then connected to an array of 12 pumps at the surface via a series of steel pipes. This yields about 1000 l/s (approximately 13m^3 of methane released per tonne of coal mined). The gas purity ranges from <35% to 60-70% (DTI 2000). This first passes through a gas treatment plant before being used in an uncompressed form to generate electricity via five 1.35 MWe reciprocal spark ignition engines. A total output of 6.5 MWe was produced, at a generating efficiency of 95%. The electricity produced is then sold to the National Grid and the colliery purchases back its own electricity requirements at Pool prices (DTI 2000). The scheme has since been extended to 8 MWe by adding a further engine and generation set.

The other two working mines in South Wales, Betws and Aberpergwm, do not operate CMM schemes and mine methane is vented to the surface as part of standard ventilation systems.

19.5 ABANDONED MINE METHANE

The potential for abandoned mine methane is linked to the state of mine water recovery which, in South Wales, is complex (see Mining Technologies Map 4), and in large areas unknown (Wardell Armstrong 2000b). This is related to a number of factors including the extent of workings, degree of interconnectivity of workings, date of mine closure and whether there is active pumping in the area. There is significant uncertainty about the extent of mine water recovery in South Wales, but there should be good AMM prospects if dry deep workings can be identified, as initial seam gas contents are high, especially in the anthracite belt (Creedy 1983, 1986, 1988, 1991). An area around the Tower Colliery has been identified that should have potential for AMM, as it would appear that mine water has not recovered in this area (Wardell Armstrong 2000b). East of this, between Aberdare and Abertillery, it would appear that mine water is beginning to recover (Wardell Armstrong 2000b), but this may still hold potential for AMM. In the north-west of the coalfield, excluding the working mine Betws, mine water is believed to have largely recovered and hence AMM prospects are probably quite poor. Elsewhere there is uncertainty about the state of mine water recovery and hence the prospects for AMM are unknown.

20 NEW TECHNOLOGY MAP 4b (South Wales)

20.1 COALBED METHANE

In the South Wales Coalfield there is a significant total thickness of coal meeting the criteria, resulting in an excellent resource base across most of the coalfield. In addition, the coalfield has the highest measured seam gas contents in the UK. The mean methane content is 13.3 m^3/tonne, based on 173 samples from 24 boreholes taken at an average depth of 702 m (Creedy 1991). Average values derived from 18 samples from 3 boreholes in the anthracite belt were 18.3 m^3/tonne at an average depth of 692 m (Creedy 1986). Values decrease from the anthracite belt towards the coalfield margins. The area with the highest resource base for CBM occurs in the north west of the coalfield, just north of Pontarddulais (see CBM areas 1 and 2 on Map 4b).

Although there is an encouraging CBM resource base, there has only been one well drilled in South Wales; the Margam Forest 1 VCBM exploration well, drilled by Enron in 1996. No details are available but the well was abandoned.

20.2 UNDERGROUND COAL GASIFICATION

The potential for UCG in the South Wales Coalfield is restricted by the extent of former underground mining that has taken place. However, potential does exist in areas away from mining, particularly in the north-west, around Llanelli and north of Pontarddulais. Between these two good areas there may be further potential but boreholes are lacking, hence the area is marked as unverifiable. This area is also marked by the presence of anthracite rank coals, which may not be optimal for gasification. Other smaller areas with good UCG potential have been identified to the south-west and south-east of Pontypridd. Elsewhere there is uncertainty and areas are marked as unverifiable. In the west, seams that meet the criteria for UCG include Big Vein and the Lower Nine Feet and in the south-east the Upper Seven Feet and the Six Feet. Other coals that reach the required thickness but occur in worked areas include the Six Feet, the combined Amman Rider-Yard-Seven Feet and the Hwch. The volume of coal suitable for gasification is indicated in Table 7.

20.3 CARBON DIOXIDE SEQUESTRATION

Coals are present below 1200 m in large areas of the coalfield, particularly in the west, between Llanelli and Port Talbot. This forms the primary resource area for CO_2 sequestration. There is also overlap between areas with high CBM resources and good UCG potential in this region, and hence there may be potential for a combined scheme. There may be potential for this technology in the nearshore areas that link Llanelli with Pembrokeshire and Port Talbot with the Gower Peninsula, although not much is known about the detailed geology in these areas.

21 MINING MAP 5a (Forest of Dean, Newent & Bristol-Somerset area)

21.1 REVIEW OF COAL IN THE AREA

21.1.1 Forest of Dean Coalfield

The Forest of Dean is one of the smaller coalfields in the British Isles. It covers an area of about 90 km^2, most of which forms part of a National Forest Park and hence the remaining coal resource is unlikely to be further exploited.

The first record of coal mining is from 1282. At that time the right of the local inhabitants, termed Free Miners, to dig for coal and iron was already recognised. On the approval of the Gaveller (the King's representative) they had the right to work Gales (defined areas of Crown land). Major exploitation of coal began in the early 1800s and, from the 1830s onwards, a number of larger collieries developed for the extraction of house coal. These were mainly in the Cinderford area. In 1904, the numerous small gales were amalgamated into seven large gales, which were exploited by large, more modern collieries. These began to work coal at greater depth, concentrating on exploiting reserves in the Coleford High Delf seam. Two of these collieries survived until 1965 when the last deep mine in the Forest of Dean closed. The main seams have been widely extracted and can be considered to be exhausted.

The coalfield consists of a broad north-south trending syncline. This is divided into two subsidiary synclines, the Main Basin to the east and the Worcester Syncline to the west, by the Cannop Fault Belt (Trotter 1942). Minor faulting along north-south and east-west trends also occurs.

The succession in the coalfield consists entirely of Upper Coal Measures. These are divided into 3 Groups: the Trenchard Group at the base, overlain by the Pennant Group and the Supra-Pennant Group (Coones 1991) (Figure 11). There are 19 coal seams within a Westphalian succession that is approximately 610 m in thickness. Coals occur in 3 main groups. The upper group comprises four thin seams of coal called the Woorgreen Delfs, none of which are of sufficient thickness to be worked. The main seams from the middle group are the Smith (or Twenty Inches), Parkend High Delf (or Lowery), Starkey, Rockey, Churchway High Delf and the Brazilly (Figure 11). They have been extensively worked in the Cinderford area. The most important seams in the lower group are the Yorkley, Whittington, Coleford High Delf and the Trenchard. More recent workings were concentrated in this lower group, with the Coleford High Delf and the Trenchard seams forming the main seams of interest. These occur at depths of around 400 and 450 m.

The Coleford High Delf is a high volatile, non-caking coal (Trotter 1942, Appendix II). There is no data available on methane content but mines were known not to be gassy and there was a tradition of working the mines with naked flames, hence it can be assumed that methane contents were low. The mines were known to be very wet.

21.1.2 Newent Coalfield

The Newent Coalfield is mostly concealed beneath Permo-Triassic strata but the coalfield is believed to form a small (19 km^2) narrow strip of Upper Coal Measures, Westphalian D age strata that lies on the western edge of the Worcester Basin.

The Newent Coalfield saw limited underground coal mining operations, mainly between 1760 and 1810 and the coals were known to be of inferior quality, being particularly rich in sulphur (Worssam et al. 1989).

The structure of the coalfield is complex but is thought to consist of a narrow NNE-SSW trending syncline (Glover et al. 1993). The western limb dips at 30°. The succession is known in most detail from two adjacent BGS boreholes (Lower House 1 and 2) which proved a Westphalian succession at least 208 m in thickness, with 19 coal seams proven, 7 of which are greater than 0.4 m thick (Worssam et al. 1989). A generalised stratigraphy for this coalfield is shown in Figure 11.

21.1.3 Bristol-Somerset Coalfield

The Bristol-Somerset Coalfield covers a broadly triangular area of approximately 1000 km^2, stretching from Cromhall in Gloucestershire in the north to Frome in Somerset in the south, and Nailsea in the west (Map 5).

Structurally the coalfield is separated into distinct basins by a complex series of major folds cut by thrust faults. These divide it into four distinct, but essentially contiguous coalfield areas:

- The Bristol Coalfield (mainly comprising the Coalpit Heath Syncline)
- The Somerset Coalfield (mainly comprising the Radstock Syncline and Pensford Syncline which are separated by the Farmborough Fault)
- The Nailsea Coalfield and Gordano outlier
- The Severn or Avonmouth Coalfield

The Westphalian succession is best known from the Radstock Syncline area of the Somerset Coalfield where Lower, Middle and Upper Coal Measures have been proven, containing 20 extensively worked seams, 0.3 to 2.0 m thick (Glover et al. 1993; Barton et al. 2002) (Figure 12). The Lower Coal Measures, approximately 150 m in thickness, rests unconformably on Devonian and Dinantian rocks (Kellaway & Welch 1993). The Ashton Little (0.6 m) and the Ashton Great (0.9 m) are the two main worked seams in the Lower Coal Measures (Figure 12). The Middle Coal Measures is typically about 375 m thick with the main seams being the Kingswood Little (0.5-0.7 m), the Kingswood Great (1.1-3.4 m) and the Lower Five Coals. The Upper Coal Measures is thought to be up to 1000 m in thickness and comprises the Pennant Sandstone and the Supra-Pennant formations. In the Upper Coal Measures a number of good coking coals have been worked, including the Parrot (0.3 – 3.0 m), Buff (0.3 – 2.7 m), Rag (0.3 – 4.0 m) and Millgrit (0.3 – 3.0 m) (Barton et al. 2002). At the top of the Coal Measures are eleven Bromley coals, eight of which are greater than 0.5 m in thickness, and eight Pensford coals, two of which have been extensively worked (Barton et al. 2002). Thick sandstones are present in the Upper Coal Measures.

The Bristol Coalfield is separated from the Somerset Coalfield by the Speedwell thrust fault-Kingswood Anticline structure. Within the coalfield the main structure is a NNE-WSW trending syncline, termed the Coalpit Heath syncline. Here coals have been proved down to a depth of at least 1056 m (unbottomed). Mainly the Lower and Middle Coal Measures are present, with only a thin development of the lower part of the Upper Coal Measures preserved. The most important coals occur within a 500 m thick Lower and Middle Coal Measures interval. The main coals of interest are the Ashton Great (1.2m), Yate Hard (2.3 m), Yate Soft (2.9 m), Lower Five Coal (1.27m) and the Upper Five Coal (1.23m) (Figure 12).

The succession in the Nailsea Coalfield comprises approximately 270 m of Lower and Middle Coal Measures strata with 12 coals known (Barton et al. 2002). Only the White's Top (1.1 – 1.4 m) and the Dog (0.4 - 0.9 m) coals have been extensively worked (Barton et al. 2002). Approximately 170 m above the White's Top seam is the Grace's Coal, which forms part of the Pennant Sandstone Formation (Figure 12).

The Avonmouth Coalfield is almost completely concealed beneath Mesozoic strata. Two seams have been proven here, the Avonmouth No.1 and 2 (Barton et al. 2002), which are thought to occur within the Farrington Member at the base of the Supra-Pennant Formation. The Avonmouth No.1 seam is locally up to 2.26m in thickness and the No.2 is up to 1.5 m in thickness (Figure 12), although both occur at shallow depths (typically less than 110 m) and are only present over an area of less than 5 km^2 (Kellaway & Welch 1993).

Coals are generally bituminous in rank with strong coking properties (Glover et al. 1993). There are no methane measurements available but the coal mines were known to be worked using naked flames, indicating very low methane contents (Glover et al. 1993), the exception being in the lower seams of the Lower and Middle Coal Measures in the extreme south of the Somerset Coalfield, where firedamp was recorded. Most of the coals are at fairly shallow depth, although in the deeper parts of the Radstock Basin of the Somerset Coalfield they occur at depths in excess of 1200 m (Map 5).

21.2 OPENCAST COAL MINING

In the Forest of Dean Coalfield, surface and near surface coal that has potential for opencast mining occurs within an area of 90 km^2. However, this area forms part of a National Forest Park and hence the resource is unlikely to be exploited. The Newent Coalfield is much smaller (at 19 km^2) and hence the potential for opencast workings is low. Much of the Bristol-Somerset Coalfield is concealed by younger, Mesozoic strata, although areas where coals are present close to surface that are suitable for opencast mining do exist, particularly in the Bristol Coalfield, to the east and north east of Bristol and in the Pensford Syncline further south. Much of these districts are urban which will reduce the area that can be exploited.

21.3 UNDERGROUND COAL MINING

There are no large working deep mines presently active in the Forest of Dean, Newent and the Bristol-Somerset coalfields. In the Forest of Dean, post-1904 mining concentrated on 5 major coal mining areas exploiting reserves in the Coleford High Delf seam. Extensive underground mining of this seam continued until the 1960 when mining ceased. Small scale underground mining operations have continued after that. Map 5a shows that the area covered by former underground workings is quite extensive, severely limiting the potential in this coalfield.

No data on the extent of underground workings in the Newent Coalfield was available to this study. However, it is known that limited underground coal mining operations did take place in this coalfield up to the late 19th century. The small size of this coalfield, the unknown extent of former workings and the poor coal quality means that prospects for future underground mining operations are very poor.

The Bristol-Somerset Coalfield has a history of underground coal mining that dates back to at least 1223. The Nailsea Coalfield was abandoned in the 19th century and mining ceased in the Bristol Coalfield north of the River Avon in 1949, with the closure of the Coalpit Heath Colliery. The last pit in Somerset was Writhlington/Kilmersdon, which closed in 1973. Map 5a shows that former underground workings are not extensive and are mainly confined to the central parts of the Radstock, Pensford, Nailsea and Coalpit Heath synclines. On the flanks of these structures the Coal Measures are typically buried beneath Mesozoic strata and there are few deep boreholes. Hence there may be potential for further mining in these areas but data is limited.

21.4 Coal Mine Methane

There is no coal mine methane resource in this area.

21.5 Abandoned Mine Methane

In the Forest of Dean, mine water pumping operations ceased after closure of the mines in the 1960s (Wardell Armstrong 2001a). There is relatively good interconnection between all the workings. As the mines were located on hills, drainage of mine water could occur under the influence of gravity. Water was channelled away by the construction of drainage adits known as soughs. It is known that all workings are flooded up to the level of the soughs and, in places, water is emerging from the soughs (Aldous et al. 1986). Thus there are no AMM prospects in this area.

In the Newent Coalfield mining ceased in the late nineteenth century and hence all the mines are thought to be flooded. Thus there are no AMM prospects in the Newent Coalfield.

In the Bristol and Somerset coalfields groundwater recovery is thought to have taken place and is probably complete. Historically, firedamp was not a problem in this coalfield and coals were worked with naked lamps. Hence AMM prospects are very poor because of the combination of mine water recovery and likely very low initial methane content of coals in these mines.

22 NEW TECHNOLOGY MAP 5b (Forest of Dean, Newent & Bristol-Somerset area)

22.1 Coalbed Methane

The Forest of Dean Coalfield has low potential for VCBM production. The total coal thickness in the southern area was up to 9.75 m and in the northern area up to 7.6 m. However, the coalfield has been worked since Roman times and the major seams have been almost totally extracted. The seam gas content has not been measured but circumstantial historical evidence (naked lamp working, almost total absence of firedamp in the mines) suggests it is very low.

The Newent Coalfield is a narrow strip of Upper Coal Measures of Westphalian D age. One borehole (Lower House 2) proves 3 seams that meet the criteria for CBM although, by analogy with the Westphalian D coals of the Forest of Dean Coalfield, coal rank and methane contents is likely to be very low. Furthermore, the resource area is of limited size. Hence CBM potential is thought to be very low.

In the Bristol and Somerset coalfields the Priston borehole proves 2 seams that meet the criteria for CBM. There are no published measurements of seam gas content in either coalfield. However, there was an almost complete absence of firedamp in the mines, the exception being in the Lower and Middle Coal Measures seams which come to surface on the extreme southern edge of the Somerset coalfield. Hence these coalfields are considered to have very limited potential for VCBM production because they probably contain low volumes of coalbed methane, at least at shallower depths.

22.2 UNDERGROUND COAL GASIFICATION

In the Forest of Dean Coalfield there are no deep boreholes (i.e. in excess of 350 m). However, data from shallow boreholes did not prove any coals in excess of 2 m in this coalfield, suggesting that UCG potential is extremely low.

In the Newent Coalfield there are no deep boreholes >262 m deep, so no UCG resource is verifiable. Only one seam in the Lower House 1 borehole meets the thickness criteria. This unnamed coal, 2.8 m in thickness, is present at a depth of 103 m below surface hence does not reach the required depth for UCG. A further unnamed seam present in Lower House 2 borehole is 1.99 m in thickness and occurs at a depth of 181 m.

Boreholes examined during this study indicate that there is no UCG potential in the Bristol-Somerset coalfields. However, three seams, the Middle Coal Measures Yate Hard (2.3 m) and Kingswood Great (1.1-3.4 m) and the Upper Coal Measures Parrot Seam (0.3 – 3.0 m), meet the thickness criteria for UCG locally and it is possible that these or other thick coals may be present in the deeper parts of the coalfield (e.g. in the Coalpit Heath and Radstock synclines).

22.3 CARBON DIOXIDE SEQUESTRATION

There are no coals present at depths greater than 1200 m in either the Forest of Dean or the Newent coalfields. This, combined with the low potential for CBM and UCG, makes these unfavourable coalfields for CO_2 sequestration. Coals are present at depths >1200m in the Radstock Syncline in the Bristol-Somerset Coalfield and hence this area could have potential for carbon dioxide sequestration. The poor CBM, and lack of UCG resources, means that prospects for carbon dioxide sequestration in association with these two technologies is highly unlikely.

23 MINING MAP 6a (Oxfordshire & Berkshire)

23.1 REVIEW OF COAL IN THE AREA

Boreholes drilled in the 1970-80s proved a southerly concealed extension to the Warwickshire Coalfield under Oxfordshire and Berkshire, covering an area of approximately 3600 km^2 stretching as far south as Reading (Foster et al. 1989). This area has never been mined. The coal-bearing strata, of Westphalian age, lie beneath Tertiary to Triassic cover rocks at depths of 400-1500 m. Immediately overlying the Coal Measures is a thin sequence of Sherwood Sandstone Group (Triassic) sandstones. This is in turn overlain by Jurassic and Cretaceous rocks, and Cainozoic strata in the south.

Lower and Middle Coal Measures strata are known locally in the south (e.g. in the Aston Tirrold borehole), but these successions are thin, lack thick coals and occur interbedded with igneous rocks (Foster et al. 1989). The main coals occur in the Upper Coal Measures and rest unconformably on older strata (Foster et al. 1989). The best seams are located within the Arenaceous Coal, Witney Coal and Burford Coal members of the Pennant Sandstone Formation (Warwickshire Group) (Figure 13). In the Apley Barn Borehole coal forms 1.23, 6.97 and 3.76 % respectively of these members. They occur at depths from 400-1500 m.

The Arenaceous Coal Member is approximately 278 m in thickness and is dominated by sandstones; with up to 11 seams totalling 5.6 m of coal, forming up to 1.23% of the member. The thickest coals (AB39-41), up to 1.9 m thick, occur at the base of the member (Figure 13). The overlying Witney Coal Member is restricted to the north of the area and thins northwards. It is 83 m in thickness in the Apley Barn Borehole and contains up to 10 seams (AB21-30) totalling 7 m in Apley Barn Borehole. The thickest coal is AB/27 at 1.6 m. The Crawley Member is 204 m in thickness in the Apley Barn Borehole, with 5 seams totally 1.2 m of coal. The thickest coal, AB/17, is 0.56 m thick. The Burford Coal Member is 137 m in thickness in the Apley Barn Borehole, comprising 12 seams totalling 7.2 m of coal. Coals AB/8 and AB/12 are 1.44 m and 1.63 m in thickness respectively. The youngest unit, the Windrush Member, is 195 m in thickness in the Apley Barn Borehole, comprising 3 seams totalling 0.55 m of coal.

The mean methane content of the coals in the Oxfordshire-Berkshire Coalfield, derived from 57 samples from 6 boreholes, is 0.4 m^3/tonne (Creedy 1991). Seams are of low rank and comprise high volatile bituminous coals.

The main structures within this coalfield are two north-westerly trending folds, the Oxfordshire and the Berkshire synclines (Foster et al. 1989). These are separated by a structural ‘high’ that runs just north of the Harwell HW3 borehole (Glover et al. 1993).

23.2 OPENCAST COAL MINING

No part of this coalfield occurs at depths suitable for opencast mining.

23.3 UNDERGROUND COAL MINING

There has been no mining within this coalfield. The most southerly mining that has taken place is associated with the workings at Daw Mill and the former Coventry Colliery in the Warwickshire

Coalfield. Within the Oxfordshire-Berkshire Coalfield, individual boreholes prove the presence of thick coals in the Upper Coal Measures that occur at depths suitable for mining (e.g. the Milton seam is 2.4m thick in the Ufton borehole, at a depth of 906 m). However, boreholes tend to occur in isolation and no area has yet been proven suitable for deep mining. The best known area is the Hawkhurst Moor prospect in the Warwickshire Coalfield.

23.4 COAL MINE METHANE

The Oxfordshire-Berkshire Coalfield has never been mined so there is no CMM potential.

23.5 ABANDONED MINE METHANE

There are no AMM prospects in this area.

24 NEW TECHNOLOGY MAP 6b (Oxfordshire & Berkshire)

24.1 COALBED METHANE

The Oxfordshire-Berkshire Coalfield comprises a large area with numerous coals that meet the criteria for CBM. However, the coalfield has an average measured seam methane content of 0.4 m^3/tonne, at a mean depth of 702 m (Creedy 1991). This low methane value results in a low resource density (6) and indicates that the prospects for CBM in this area are very poor.

24.2 UNDERGROUND COAL GASIFICATION

Three main areas in the Warwickshire and Oxfordshire-Berkshire coalfields meet the criteria for UCG. The most promising is in the north, forming an area of 336 km^2 to the south and south-east of the Daw Mill Colliery workings. Part of this area is also shown on Map 7. The main coal that has UCG potential in this area is the Thick Coal, although both the (Upper Coal Measures) Broughton and Milton seams are locally in excess of 2 m. Areas with UCG potential occur further south, in the districts south of Banbury and east of Witney. Coals suitable for gasification in these areas are in the Upper Coal Measures and include the Top Broughton, Low Milton, Eynsham and Apley seams. The volume of coal suitable for gasification in these three areas is indicated in Table 7. Large areas of this map have unverifiable potential, due to the lack of deep boreholes. These could have potential and merit further investigation. Other areas, e.g. west of Oxford and north of Newbury, are known to have poor UCG potential.

24.3 CARBON DIOXIDE SEQUESTRATION

A large north-south trending area between Coventry and Oxford, where Coal Measures occur at depths greater than 1200 m, could be suitable for carbon dioxide sequestration. A further area where coals are at a suitable depth occurs north of Newbury. Carbon dioxide sequestration may also be feasible across all areas where CBM and UCG can take place. The best location for such a scheme would occur where there are good prospects for UCG as methane contents are low in this coalfield.

25 MINING MAP 7a (South Staffordshire, Warwickshire, Leicestershire, South Derbyshire & Shropshire)

25.1 REVIEW OF COAL IN THE AREA

25.1.1 Shrewsbury Coalfields (Hanwood, Leebotwood and Dryton)

The Hanwood, Leebotwood and Dryton coalfields form small subdivisions within the larger Shrewsbury Coalfield. The total area of the coalfield is approximately 200 km^2. The coal-bearing strata comprise the Halesowen and Salop formations, part of the Warwickshire Group, of Westphalian D age (Figure 14). They onlap onto Precambrian and Lower Palaeozoic strata to the south-west and south and are overlain by Permo-Triassic strata to the north-east (Pocock et al. 1938). The Halesowen Formation is generally not very deeply buried (<200m) in this area. The main structures within the coalfield are a series of large north-east to south-west trending faults, together with a number of smaller north-south and east-west faults.

Mining has taken place in this area for many centuries and in the 19th century there were nine reasonably sized collieries and many smaller ones. By 1921, these had all closed except for Hanwood Colliery, which continued until its closure in 1941. One notable feature of the Hanwood Colliery was the exceptionally low gas content of the coal, which allowed the use of naked flames underground. Records exist of workings in five seams including the Half Yard, Yard, Main, Thin and Best (Figure 14). The Half Yard, worked at depths of about 140 m at the Hanwood Colliery, was known to produce a very high grade of coal, with a calorific value of approximately 15,826 kJ. At the Cruckmede Shaft the Half Yard is 0.46 m in thickness and the Main is 1.22 m, at a depth of 130 m.

25.1.2 Coalbrookdale Coalfield

The Coalbrookdale Coalfield, covering an area of approximately 80 km^2, is centred on the town of Telford. The main part of this coalfield stretches from Lilleshall in the north down to Broseley. A thin (2 km) strip of outcropping Coal Measures links the coalfield with the Wyre Forest Coalfield, 13 km to the south. At its broadest it has a width of 6 km. The main structures within the coalfield are a series of north-east to south-west trending folds that have been cut by numerous north-east to south-west trending faults. The coalfield is fault-bounded to the north by the north-east to south-west trending Boundary Fault; older (Lower Palaeozoic) strata are present to the west and south-west and to the east the coalfield dips below later Carboniferous successions (Etruria and Halesowen formations) and Permian and Triassic sandstones. The coalfield forms the western edge of the Stafford Basin and links up with the South Staffordshire Coalfield in the subsurface.

Carboniferous strata range in age from Langsettian to possibly Stephanian. Most of the coals are present in the Langsettian and Duckmantian (Lower and Middle Coal Measures), although workable coals do occur in the Upper Coal Measures (Halesowen Formation). The Lower Coal Measures are thickest in the north-east, reaching about 100 m (Bridge & Hough 2002). The greatest thickness of Middle Coal Measures is 1545.2 m in the Childpit Lane Borehole (Bridge & Hough 2002). The worked seams include Fungous, Top Coal, Threequarters, Double, Yard, Big Flint, New Mine, Clunch, Two Foot, Best, Randle, Clod and Little Flint (Figure 15). Coals are ranked as high volatile, very weakly caking to weakly caking (Bridge & Hough 2002). The Threequarters and the Double are the thickest seams in the coalfield (Hamblin & Coppack 1995). Coals are of unusually low sulphur content and of low rank (Hamblin et al. 1989).

There are no methane measurements for the Coalbrookdale Coalfield, although it is known that the methane drainage system from Granville Colliery was connected to the Wellington Gas Works (Bridge & Hough 2002). In 1973 approximately 6900 m^3/hr of methane was derived from boreholes driven upwards from the Double Coal (Hamblin et al. 1989).

25.1.3 Clee Hills Coalfield

This forms part of a prominent outlier at Titterstone Clee and Brown Clee. Coal mining started here in medieval times. The Clee Hill Coalfield was the highest coalfield in England and the coal was accessed via adits and bell pits. Coals are believed to be Duckmantian (Middle Coal Measures) in age (Glover et al. 1993). Five coal seams are known to have been worked in the area, down to depths of approximately 120 m: the Great, Three Quarters, Smith, Clunch, Four Feet and the Yard, with five of the major seams present in a 30 m interval (Figure 16). The thickest coal is the Great, which is up to 2.13 m in thickness. The deepest borehole penetrates down to 200 m. The coalfield is bounded to the north and south by large north-east to south-west trending faults.

25.1.4 Wyre Forest Coalfield

The Wyre Forest Coalfield and its southern extension, the Mamble Coalfield, is approximately 30 km long and up to 12 km wide and is connected via a narrow strip of outcropping Coal Measures to the Coalbrookdale Coalfield to the north. In this basin, both Middle and Upper Coal Measures are present, with the worked seams occurring towards the top of the Middle Coal Measures, close to the Aegiranum Marine Band. The main seams are the Brooch, Half Yard, Four Foot and Two Foot Seams (Whitehead & Pocock 1947) and, in the main part of the Wyre Forest Coalfield, the Brooch, and New Mine seams have been worked (Figure 17). Coal was worked down to depths of about 300 m.

In the Mamble area the worked seams include the Hard Mine and the upper leaf of the Main, known as the Three Quarters (Mitchell et al. 1962). Both coals attain a thickness of about 2 m, including bands of partings. Coals improve in thickness and quality in the central part of the Mamble Coalfield, across an east-west belt.

The main structure in the area is a series of main north-south and north-east to south-west trending faults and ENE-WSW trending cross-faults.

25.1.5 West Staffordshire

This is an area of concealed Coal Measures that lies beneath the Permo-Triassic strata of the Stafford Basin. It represents the subsurface extensions to the North and South Staffordshire coalfields and links westwards with the Shrewsbury Coalfield. The towns of Newcastle-under-Lyme, Stafford, Wolverhampton, Bridgnorth, Kidderminster and Telford line its perimeter. The Coal Measures are deeply buried in the central part of the Stafford Basin, at depths of around 1000-1200 m (Glover et al. 1993). Around the margins the Coal Measures come to crop and form the coalfields that fringe the basin. The succession thins towards the south, where it is less than 150 m in thickness. Associated with this, coals become thinner and less persistent. In the north numerous coals are present in an interval of Lower and Middle Coal Measures from 250-300 m in thickness. Overlying the Coal

Measures in the Stafford Basin is a thick succession of red Upper Coal Measures and Permo-Triassic strata, including the important Bridgnorth Sandstone aquifer.

The stratigraphy of the coals is not well known and coal seam nomenclature varies, with both the Coalbrookdale and South Staffordshire seam names used (Figure 15). Coals are likely to be of high volatile, very weakly caking to weakly caking rank (Bridge & Hough 2002). There are no direct measurements of methane content in this area. The nearest are from the South Staffordshire Coalfield (Littleton area), where Creedy (1991) records a mean methane content of 3.3 m^3/tonne.

The structure of the area is poorly known but is likely to be similar to the adjacent coalfield areas. These are dominated by north-east to south-west and some north-south trending fault systems.

25.1.6 South Staffordshire Coalfield

The exposed coalfield, covering an area of 400 km^2, is elliptical in shape, extending from Rugeley in the north to Halesowen in the south. It is bounded to the west by the Western Boundary Fault and to the east by the Eastern Boundary Fault. To the north, the Coal Measures extend and dip northwards beneath Triassic cover to the Swynnerton Fault. The coalfield can be divided into two main parts, Cannock Chase in the north and the Black Country area in the south, separated by the east-west trending Bentley Fault in the Walsall area.

The thickest coals are in the Lower and Middle Coal Measures. To the north and west, away from outcrop, the Coal Measures are overlain by reddened Upper Coal Measures that are mainly barren of workable coal seams. These consist, in ascending order, of the Etruria Formation, Halesowen Formation, Salop Formation and Clent Formation (Powell et al. 2000). Above this the Carboniferous is unconformably overlain by Triassic strata, consisting of the Sherwood Sandstone Group in the east, west and north and the Mercia Mudstone Group in the south. The main structures within the coalfield are a series of NE to SW, NW-SE and east-west trending normal faults.

The thickest seams in the Black Country area are the Brooch, Flying Reed, Thick, Heathen, Stinking, New Mine, Fireclay and Bottom (Figure 18). The Thick Coal is typically 4-5 m in thickness, although it can be up to 10 m in places (e.g. Timbertree Colliery) south-east of Dudley. In the Cannock Coalfield the Thick Coal splits into a number of component seams, including the Benches, Eight Feet and Park. This is associated with a gradual increase in the thickness of the intervening strata, such that, at Littleton Colliery, near Cannock, the thickness of strata represented by the Thick Coal is 52 m. The main coal seams in the Cannock Chase area are the Top and Bottom Robins, Benches, Eight Feet (Wyrley Bottom), (Old) Park, Heathen, Stinking, Yard, Bass, Cinder, Shallow, Deep and Mealy Grey (Figure 18).

The measured methane content of seams in the Cannock Coalfield is low, with a mean methane level of 3.3 m^3/tonne in seams in Littleton Colliery quoted by Creedy (1991), based on 119 samples from a mean depth of 775 m. There are no data on coal rank or methane content in the Black Country area.

25.1.7 East Staffordshire

This is a concealed area of Coal Measures linking the South Staffordshire, Warwickshire and South Derbyshire coalfields. Lichfield and Tamworth lie at the centre and southeast of the area respectively. Its eastern limit is the Netherseal Fault, beyond which it is contiguous with the South Derbyshire Coalfield. The southern margin is marked by the Western Boundary Fault of the Warwickshire Coalfield, the north-east to south-west trending Birmingham Fault and the eastern margin of the South

Staffordshire Coalfield. The western boundary is taken at the Stafford Fault just to the west of the Park Prospect and, to the north, the succession becomes progressively older, until the margin of coal-bearing strata can be defined by the subcrop of Namurian rocks against the Permo-Triassic. Only limited underground mining has taken place in this area, predominantly along the eastern margins of the South Staffordshire Coalfield (e.g. at Lea Hall, Littleton, Brereton and Hamstead collieries) where the Bottom Robins, Park, Eight Feet, Benches, Yard, Deep, and Shallow were worked in the north and the Thick Coal was worked in the south.

The generalised sequence of coal seams likely to be encountered in a complete succession is shown in Figure 19. The stratigraphy is similar to that of the South Staffordshire Coalfield. The main coals lie in the Lower and Middle Coal Measures. In the north the thickest coals are the Top and Bottom Robins, Park, New Mine, Shallow and Deep which are greater than 2 m in thickness, although at least a further 14 seams occur in the succession that are greater than 0.4 m in thickness in places (Figure 19). The average seam thickness is 1.1 m. In the south the Benches, Eight Feet and Park combine to form the Staffordshire Thick Coal, which is locally up 5 m in thickness. The target sequence for these coals is likely to lie in the depth range between 500-1100 m.

The structure of this area is complex. In the north the main structure is an anticline, with the axis trending roughly north-south. In the main part of the basin, around Lichfield, the succession dips to the south-east.

Data from the Whittington Heath borehole show that the rank of the coal seams is high volatile bituminous, with rank codes in the range 602 to 902 (Glover et al. 1993). The mean methane content of coals derived from 201 samples in 21 boreholes is 1.5 m^3/tonne (Creedy 1991). Given the low rank, and its position adjacent to the South Derbyshire Coalfield, which also has very low seam gas contents, it is unlikely that the area has significant coalbed methane potential.

25.1.8 Warwickshire Coalfield

The Warwickshire Coalfield is an elongate north-south trending coalfield, 45 km in length and 13 km in width, lying beneath the towns of Warwick, Royal Leamington Spa and Kenilworth. The main structure within the coalfield is a broad, open, southwards-plunging syncline. The Warwickshire Coalfield passes southwards without interruption into the Oxfordshire-Berkshire Coalfield and the boundary between the two is generally taken where coal-bearing Upper Coal Measures incrop against younger strata. The coalfield is fault-bounded to the west and east by the Maxstoke-Western Boundary and Eastern Boundary or Polesworth faults respectively. Triassic strata occur on all sides of the coalfield. The other important structure is the Fillongley Anticline, which is a major NE-SW trending faulted anticline that runs through the southern part of the Daw Mill Colliery licence area.

The main coals are in the Lower and Middle Coal Measures. They are generally high-volatile, low-rank, bituminous coals (British Coal Rank 902) (Glover et al. 1993). In the north-western part of the coalfield the Coal Measures are about 260 m thick and contain the following main coal seams: Four Feet, Thin Rider, Two Yard, Bare, Ryder, Ell, Slate, High Main, Smithy, Seven Foot, Deep Rider, Deep, Top Bench and Bench (Figure 19).

In the south of the coalfield the main seam of interest is the Warwickshire Thick Coal, which averages 6 m in thickness (Figure 20). The leaves of the Thick Coal have average sulphur contents of less than 4% by weight and average ash contents of less than 9% by weight (air-dried basis) (Fulton 1987). The seam has a calorific value of 28,000 kJ/kg (Drake 1982). Coal quality, calorific value and rank decrease and ash and chlorine increase towards the south-east (National Coal Board 1957). Methane content has been measured at 2.5 m^3/tonne in the Thick Coal at Daw Mill (Creedy 1986), although Creedy (1991) quotes an average figure of 1.7 m^3/tonne for the coalfield as a whole. The prime area for the Thick Coal lies between Daw Mill and the former Coventry Colliery (Cope & Jones 1970; Bridge et al.1998). To the north and south of this area the seam splits into a number of separate seams collectively known as the Thick Coal Group. This includes the Thin Ryder, Two Yard, Bare, Ryder, Ell, Nine Feet and High Main.

To the east of the main coalfield is the Bulkington prospect. This area, 7.5 km^2 in size, comprises a westwards dipping sequence of Coal Measures concealed by a thin cover of Triassic strata (Bridge et al. 1998). The BGS Well Green Farm borehole proved 107 m of Lower and Middle Coal Measures, including 11 coals, resting on Cambrian rocks (Bridge et al. 1998).

25.1.9 South Derbyshire Coalfield

The South Derbyshire Coalfield is a north-west to south-east trending coalfield located to the south-east of Burton-on-Trent. It covers an area of approximately 36 km^2, and is contiguous to the west, beyond the Netherseal Fault, with the East Staffordshire area of concealed Coal Measures. It is connected to the adjacent Leicestershire Coalfield to the east by the north-west trending Ashby anticline.

Coals are known from the Lower, Middle and Upper Coal Measures. The main seams are the Upper Kilburn, Block, Little, Little Kilburn, (Over & Nether) Main, Little Woodfield, Lower Main, Woodfield, Stockings, Eureka, Stanhope, Kilburn, Fireclay and Yard (Figure 21). The succession is approximately 760 m thick (Carney et al. 2001). The Lower Coal Measures is about 330 m thick (Fulton & Williams 1988) and the Middle and Upper Coal Measures combined are from 350 to 400 m (Carney et al. 2001). Above the Upper Kilburn seam the nomenclature changes to the ‘P’ series, devised by Jago (in Worssam et al. 1971). These are characterised by numerous thin seams with thin intercalations of siliciclastic sedimentary rocks (Carney et al. 2001). This represents a highly condensed succession compared with North Derbyshire and Nottinghamshire (Frost & Smart 1979; Carney et al. 2001).

The mean methane content of the seams is 1.3 m^3/tonne (36 samples from 5 boreholes) (Creedy 1991). The seams in the South Derbyshire Coalfield are mainly high volatile and non-caking (Coal Rank Code 802). There is very little variation in rank across the coalfield (Glover et al. 1993). Seams in the South Derbyshire Coalfield are fairly shallow, typically less than 450 m in the deepest parts of the coalfield (Glover et al. 1993).

Structurally, the coalfield is bounded to the east by the NNW-SSE trending Boothorpe Fault. The coalfield forms a broad synclinal structure, with the axis trending parallel to the Boothorpe Fault. The coalfield is affected by numerous small faults trending NNE-SSW, ENE-WSW, NNW-SSE, and N-S. A number of folds also occur, trending NNE-SSW and ENE-WSW.

25.1.10 Leicestershire Coalfield

The Leicestershire Coalfield is located just to the east of the South Derbyshire Coalfield. The exposed coalfield covers an area of approximately 52 km^2. Seams in the Leicestershire Coalfield are restricted to the Lower and Middle Coal Measures and are fairly shallow, typically less than 350 m in the deepest parts of the coalfield.

The Lower and Middle Coal Measures are approximately 340 and 140 m in thickness respectively (Carney et al. 2001). The Lower Coal Measures contain some 12 named seams and the Middle Coal Measures have 9. The thickest seams are the Excelsior, Minge, Five Feet, New Main, Upper & High Main, Middle Lount, Nether Lount and Lower Main (Figure 22). Coals are mainly high volatile and non-caking (Coal Rank Code 802). There is very little variation in rank across the coalfield (Glover et al. 1993). The mean methane content of the seams in this coalfield is 0.5 m^3/tonne, derived from 68 samples in 13 boreholes (Creedy 1991).

The main structure within the coalfield is a syncline, bounded to the east by the NW-SE trending Thringstone Fault. The coalfield is separated from the adjacent South Derbyshire Coalfield by the NW-SE trending Ashby Anticline. Most of the coalfield has low dips, typically 4 degrees to the east (Fox-Strangways 1907; Glover et al. 1993).

25.2 OPENCAST COAL MINING

25.2.1 Shrewsbury Coalfields (Hanwood, Leebotwood and Dryton)

There are no known opencast sites in the Shrewsbury coalfields and prospects are thought to be limited by the thick covering of superficial drift deposits in the area, which can be up to 50 m thick in places.

25.2.2 Coalbrookdale Coalfield

There have been a large number of opencast sites in this coalfield, particularly along the western fringe, where coals are at outcrop. Opencast operations were common during the Second World War and there has been an almost unbroken succession of sites to the present day (Hamblin et al., 1989). Large areas were opencasted for coal around the south-western side of Telford, the restoration of which was associated with the development of Telford New Town in the 1970s. Opencast activity is now confined to the area south-west of Telford and south of the River Severn, where seams of the Lower Coal Measures (Little Flint to New Mine) crop out (Bridge & Hough 2002). Accessible resources are now thought to be largely depleted and the potential for future developments is limited (Bridge & Hough 2002).

25.2.3 Clee Hills Coalfield

Coals are present at outcrop in the Clee Hills Coalfield and technically would be suitable for opencast mining.

25.2.4 Wyre Forest Coalfield

This coalfield has limited opencast potential because the highest coals in the succession tend to the thin (i.e. <0.2 m in thickness) and occur at depths in excess of 50 m. There may be instances locally where there are good prospects.

25.2.5 West Staffordshire

This area refers to the subsurface extension that links the South Staffordshire with the Coalbrookdale Coalfield. Hence there is no opencast potential.

25.2.6 South Staffordshire Coalfield

Most of the past sites are situated in the north of the coalfield, in the Cannock area and potential still exists there. Further south much of the coalfield lies beneath the Wolverhampton-Dudley-Birmingham conurbation. This restricts the areas suitable for opencast mining somewhat, although there may be potential for mining at brown field sites.

25.2.7 East Staffordshire

This area refers to the subsurface extension that links the South Staffordshire with the South Derbyshire Coalfield. Hence there is no opencast potential.

25.2.8 Warwickshire Coalfield

Past opencast sites were situated on the outcrop of the Coal Measures along the western and, more commonly, the eastern sides of the coalfield. Many of these data back to the immediate post-war period (Bridge et al. 1998). Prospects for further opencast coal mining still exist but are limited by the relatively narrow width of this belt of outcrop.

25.2.9 South Derbyshire Coalfield

Areas technically amenable to opencast coal mining occur in the South Derbyshire Coalfield, and there have been numerous previous opencast mines within this area. However, the coalfield is of limited size and the main constraints will be finding areas that are not urbanised and have not been previously opencasted.

25.2.10 Leicestershire Coalfield

Areas suitable for opencast coal mining occur in the Leicestershire Coalfield, and there have been numerous previous opencast mines within this area. However, as with the South Derbyshire Coalfield, the coalfield is of small scale and the same constraints will apply. As of April 2002 there were 2 working opencast sites in this coalfield (Source DTI web site: www.dti.gov.uk/energy/inform/site_installations/ dukes2_10.pdf).

25.3 UNDERGROUND COAL MINING

25.3.1 Shrewsbury Coalfields (Hanwood, Leebotwood and Dryton)

Mining has taken place in this area for many centuries and in the 19th century there were nine reasonably sized collieries and many smaller ones. By 1921, these had all closed except for Hanwood Colliery, which continued until its closure in 1941. Coals are generally thin and hence there is limited potential for future large scale underground mining operations in the outcropping part of the coalfield, although there may be prospects to the north-east, where the coal-bearing strata are concealed beneath the Permo-Triassic. The subsurface geology of this area is not well known.

25.3.2 Coalbrookdale Coalfield

The first known record of coal working in Coalbrookdale comes from 1250, although it is possible that coal was worked in this coalfield during Roman times. Coal production reached a peak in 1871, when over 1 million tonnes was produced. At nationalisation, there were 3 principal deep mines remaining open – Granville, Grange and Kemberton collieries. With the closure of Granville Colliery in 1979 through heavy faulting, underground coal mining ended in Coalbrookdale. The main part of the coalfield can be considered as exhausted, but the Coal Measures are in continuity with the South Staffordshire Coalfield beneath the Stafford Basin, and this is where the greatest potential for further underground mining is present. The Coal Measures are believed to reach a maximum depth of about 1000 m below OD (Bridge & Hough, 2002). Hence potential prospects exist in the eastern part of the coalfield. The Madeley Wood 1 borehole, for example, proves the Deep Coal, 2.07 m in thickness, at a depth of 375 m and the Double Coal, 2.13 m thick, at a depth of 406 m.

25.3.3 Clee Hills Coalfield

The last colliery to operate in the area was Barn Pit (alternatively known as Cornbrook Colliery), which closed in 1927. There was a brief revival during the Second World War for local use but all workings had ceased by 1945. The small scale of the coalfield limits the potential for future workings.

25.3.4 Wyre Forest Coalfield

The area has seen mining from at least the 17th Century and the last pit in the area (Bayton Nos.10 and 11, or Hunthouse) opened in 1954, and finally closed in 1972. There may be potential to the south and east of the main Wyre Forest Coalfield workings, although good quality deep boreholes are largely absent from this area thus making it difficult to assess the thickness and quality of seams.

25.3.5 West Staffordshire

The West Staffordshire area has significant prospects for the underground mining of coal. In particular the Park Prospect, just east of Stafford, was explored by the NCB in the 1970s. Here the Benches, Eight Feet and Park are all in excess of 2 m in thickness at depths suitable for mining. Locally the Bottom Robins, Bass and Shallow also achieve this thickness. It was intended to sink a colliery at Hopton, north-east of Stafford, in the 1980s but the project was abandoned because of the high chlorine content of the coals. There are believed to be reserves of 300 million tonnes, 100 million of which could be extracted from 10 workable seams. Further south, just west of Wolverhampton, the Thick Coal is important, varying in thickness from 2.1-5.2 m. On the opposite side of the basin, at Lilleshall, the Double seam is up to 2.9 m in thickness. In the centre of the prospect, the geology is not well known but, in the Ranton 1 borehole, it would appear that there is a coal 2.3 m in thickness at a depth of 1028 m.

25.3.6 South Staffordshire Coalfield

Currently there are no deep mines in operation in this area and, historically, the South Staffordshire Coalfield has been extensively mined. Most modern mining has been concentrated along the northern side of the coalfield, at Cannock Chase. Here, coals were first worked from 1298 onwards in the form of bell pits and by the sinking of shallow shafts. From the mid-19th century onwards, deeper and more productive mines were sunk. More recent workings were concentrated in the north and west, accessing coal from deeper shafts, e.g. the Littleton Colliery, which opened in 1905. The last mine to be opened in the area was Lea Hall, which closed in 1991 due to problems with heavy faulting. The coal from Littleton and Lea Hall had a high chlorine content which required blending with low chlorine coals from opencast sites for it to be acceptable to power stations. The last pit to be closed in Cannock Chase was Littleton, in 1993.

Further south, in the Black Country area, the Thick Coal has been principally worked. With exhaustion of shallow reserves, production declined rapidly in the 19th and 20th centuries. The last major mine to be sunk was Baggeridge, Dudley, in 1912. Deeper lying reserves were exploited using the pillar and stall method, and the Thick Coal, Brooch, Heathen and New Mine seams were worked. Its closure in 1968 marked the end of deep mined coal production in the Black Country area of the South Staffordshire Coalfield.

There is remaining potential for future underground mining potential in this coalfield, particularly on the north side of the coalfield, e.g. in the Park prospect, discussed above. It would also appear that there is potential on the western and eastern flanks of both the Cannock Chase and the Black Country areas. Just west of Wolverhampton, for example, the Thick Coal is important, varying in thickness from 2.1-5.2 m. In the Brownhills area the Bottom Robins, Wyrley Yard and Eight Feet are thick (i.e. >1.5 m), and further south, at Hamstead 1 Great Barr borehole, the Thick Coal is up to 5 m in thickness. Hence prospects are present.

25.3.7 East Staffordshire

Workings in this area belong to the Lea Hall Colliery on the west side and the Cadley Hill Colliery on the east side, parts of the South Staffordshire and South Derbyshire coalfields respectively. In the main part of the East Staffordshire area, between the Bourne Brook and Hungry Lane boreholes, there are a number of coals in excess of 2 m in thickness, and locally the Shallow and the Yard are in excess of 3 m. Hence there remains good prospectively for future underground coal workings in this area.

25.3.8 Warwickshire Coalfield

The Warwickshire Coalfield has been extensively worked from as far back as Roman times. However, deep mining and exploitation of the concealed part of the coalfield did not begin until about the second half of the 19th century, with thirteen seams being deep mined on a significant scale (Worssam & Old 1988; Bridge et al. 1998). Many new mines were opened in the 20th century e.g. Arley, Binley, Newdigate and Coventry collieries, working the Warwickshire Thick Coal. The last colliery in the coalfield, Daw Mill, opened in 1964 and is now the only operational mine. The mine exclusively works the Warwickshire Thick Coal and annual production runs at about 2 million tonnes of coal. The seam varies in thickness from 6.6 to 7.5 m and has an average sulphur content of 1.8% (IMC 2002). Reserves at this mine are estimated at c.26 million tonnes (IMC 2002). The more recent workings are in the south of the licence area, at distances of up to 8 km away from the shafts.

In terms of future underground mining the Hawkhurst Moor prospect, just to the south of Daw Mill workings has considerable potential, and reserves of over 40 million tonnes have been estimated (IMC 2002). Whilst it would be possible to access these from the current Daw Mill workings, the prospect is between 8 and 14 km south of the existing shafts. Hence the sinking of a satellite shaft would be necessary to provide ventilation, and man and material access (IMC 2002).

Coals up to 2 m in thickness are present at depths above 260 m in the Bulkington area, to the east of the presently worked coalfield and may form a prospect. In addition a prospect has been postulated to the north-west of Stratford-upon-Avon, between Stratford and Redditch, although no boreholes have proved coal in this area.

25.3.9 South Derbyshire Coalfield

The earliest records for coal mining in South Derbyshire date back to the 13th century, although coal may have been mined in prehistoric times. Underground mining operations began in an intensive way during the 18th century, and 12 seams have been worked on a significant scale (Worssam & Old 1988). The last pit in the area, Cadley Hill, closed in 1988. The outcropping part of the coalfield can be viewed as largely exhausted, leaving potential only in the west, where it joins up with the East Staffordshire prospect. In boreholes such as Walton Wood and Lady Leys, immediately west of the former mine workings, the Main seam varies from 2.8-3.5 m in thickness at depths of about 600 m.

25.3.10 Leicestershire Coalfield

This coalfield can be considered as exhausted, with little or no potential for further large scale deep mines. Study of Map 7a suggests that there is an area of outcropping Coal Measures in the north-west in which there are no old workings marked. However, this is not the case and it is known that the earliest workings, from medieval times until the end of the 18th century, were concentrated in this area (Worssam & Old 1988). Hence it is concluded that no accurate record of these workings exists or was available to this study. It is also known that the lowest part of the Lower Coal Measures comes to crop across this area and this part of the succession contains few thick coals. Later workings in the coalfield worked the area to the south. Bagworth Colliery was the last coal mine in Leicestershire and closed in February 1991, after 166 years of production.

25.4 COAL MINE METHANE

All of the coalfields shown on this map, with the exception of Warwickshire, have no working mines. Hence there is no CMM potential in these areas. Theoretically the workings of Daw Mill Colliery provide a CMM resource, although the low methane content of the Thick Coal (typically about 1.7 m^3/tonne) reduces the resource potential. During normal operations the methane content is known to be low, and the ventilation system keeps the methane percentages below 1% (Drake 1982). Hence there is little potential for CMM.

25.5 ABANDONED MINE METHANE

25.5.1 Shrewsbury Coalfields (Hanwood, Leebotwood and Dryton)

It is considered that this coalfield has a very poor potential for AMM. In this coalfield the last mine closed in 1941, and it can be assumed that mine water has now fully recovered. Even if that were not the case the coalfield was traditionally worked with naked flames, indicating low methane contents.

25.5.2 Coalbrookdale Coalfield

Underground mining in this coalfield ceased with the closure of Granville Colliery in 1979. Prior to this the colliery extracted methane for use at the Wellington Gas Works, 8 km to the west. In 1973, approximately 115 m^3/minute of methane was being obtained from boreholes driven upwards from the Double seam. This methane was used commercially until replaced by North Sea Gas. Historically though, mine water was a problem in this coalfield and levels are now thought to be fully recovered. This severely limits the potential for AMM.

25.5.3 Clee Hills Coalfield

All underground mining operations had ceased in this coalfield by 1945 and there have been surface emissions of mine water from the Titterstone Clee mine in the Clee Hills Coalfield. This indicates that mine water levels have fully recovered and so this coalfield has very low AMM potential.

25.5.4 Wyre Forest Coalfield

The last mine in this area closed in 1972 and it is thought that the groundwater conditions in the area have fully recovered, severely limiting the potential for AMM.

25.5.5 West Staffordshire

There are no mines in this area, thus there is no AMM potential.

25.5.6 South Staffordshire Coalfield

The status of mine water recovery in the Black Country is uncertain, but 11 surface emissions of mine water are known in shallow workings, showing at least partial recovery. The last colliery in the Black Country was Baggeridge, which closed in 1968. Abandoned mine methane prospects are uncertain but likely to be poor. In the Cannock Chase area, the last colliery, Littleton, closed in late 1993 and recovery of mine water to the base of the overlying Triassic succession is anticipated at Littleton before 2007 (Coal Authority 2000). At the former Lea Hall Colliery to the north-east, mine water is known to be recovering and water levels in the Mid Cannock area, 4 km to the south east of Littleton, are at least partially being controlled by pumping. Hence the area may have potential for AMM, although it is likely to be variable.

25.5.7 East Staffordshire

There are no mines in this area, thus there is no AMM potential.

25.5.8 Warwickshire Coalfield

Pumping controls mine water levels in the Daw Mill Colliery and surrounding areas. Ongoing investigations by the Coal Authority indicate that elsewhere mine water recovery is well advanced or complete in all areas except around Daw Mill Colliery. This, combined with the low mean methane content of the seams (1.7 m^3/tonne), suggests that AMM prospects are generally likely to be poor.

25.5.9 South Derbyshire Coalfield

The South Derbyshire Coalfield was generally relatively dry when worked and can be considered as a single basin with connected collieries in which there is a general rise in water levels. Mine water levels in the coalfield are recovering. In 1989, the total make of water was recorded as 1000 gallons per minute, evenly split from north to south. The remaining voids are extensive and will take many years to flood at this rate of inflow. Methane has been detected at vents at the Donisthorpe, Rawdon and Marquis shafts (>20% methane is not uncommon at Donisthorpe and Rawdon shafts). Oakthorpe and Church Gresley vent carbon dioxide. Measured seam methane contents average only 1.3 cubic metres per tonne of coal and so AMM prospects are very poor.

25.5.10 Leicestershire Coalfield

Ongoing investigations by the Coal Authority into water levels in mine workings indicate possible total recovery but it is not known if the water is static or still rising. There are known surface emissions of water at Lount and Staunton Harold. This suggests that there are not likely to be any AMM prospects in this coalfield.

26 NEW TECHNOLOGY MAP 7b (South Staffordshire, Warwickshire, Leicestershire, South Derbyshire & Shropshire)

26.1 COALBED METHANE

26.1.1 Shrewsbury Coalfields (Hanwood, Leebotwood and Dryton)

The shallow depth and low gas content of the coals suggest that the coalfield has little potential for CBM exploitation.

26.1.2 Coalbrookdale Coalfield

Seam gas contents are not known in the Coalbrookdale Coalfield, but may be slightly higher than the Shrewsbury coalfields as the seams here are from the Lower and Middle Coal Measures. The outcropping and shallow subsurface Coal Measures have been mined for centuries and are unlikely to form a good CBM resource. In addition heavy faulting and folding have severely disrupted the coalfield and are likely to have compartmentalised any CBM prospects (Glover et al. 1993). However, there may be some potential to the east where the coals become more deeply buried.

26.1.3 Clee Hills Coalfield

The CBM potential of this coalfield is unknown. There are at least 6 seams that are greater than 0.4 m in thickness (Figure 16). However, there are no boreholes that penetrate to depths >200 m to prove the theoretical potential for a CBM prospect.

26.1.4 Wyre Forest Coalfield

The Wyre Forest and Mamble coalfields contain fewer coals and more sandstone beds than the adjacent South Staffordshire Coalfield. There are no measurements of seam gas content in either coalfield. VCBM prospects are considered to be very poor but it might be expected that they will gradually improve northwards beneath the Stafford Basin.

26.1.5 West Staffordshire

CBM prospects are anticipated throughout the West Staffordshire-Stafford Basin area. In the centre of the Stafford Basin (CBM Area 4 of Map 7b), the Coal Measures are deeply buried below non coal-bearing Upper Coal Measures and Permo-Triassic strata. Boreholes (Ranton 1 and Stretton) prove that the target CBM succession lies at depths in excess of 900 m, with approximately 12 m of coal meeting the criteria. There are no published measurements of the seam methane content for this area, but an average value of 5 m^3/tonne was estimated for CBM Area 4 between Wolverhampton and Stafford. Further north, data supplied by Wardell Armstrong (2002) suggest an increase of methane content to about 9 m^3/tonne is likely (CBM Area 3).

The Park Prospect spans both CBM areas 5 and 2, with data from Wardell Armstrong (2002) indicating that seam methane levels increase from about 3 to 7 m^3/tonne towards the north-west. Hence CBM Area 2 is likely to contain a suitable resource base for CBM. However, this is speculative and nothing is known about the permeability of the coals in this area.

26.1.6 South Staffordshire Coalfield

The extensive former underground coal workings preclude this area from being a CBM prospect. In addition the measured methane content of seams in the Cannock Coalfield is probably too low to be of commercial interest for the foreseeable future. A mean methane level of 3.3 m^3/tonne in seams in Littleton Colliery was quoted by Creedy (1991), based on 119 samples from a mean depth of 775m.

26.1.7 East Staffordshire

The East Staffordshire area includes CBM areas 5, 6 and 8 on Map 7B. The average seam thickness is approximately 1.1 m and there are up to 18 seams that can meet the criteria (Glover et al. 1993). However, seam methane contents are thought to be low (from less than 1 up to 4 m^3/tonne) and hence methane in this area is considered to be too low to form a CBM prospect. It is likely that both rank and methane content will increase with depths but there are no data to substantiate this (Glover et al. 1993).

26.1.8 Warwickshire Coalfield

The Warwickshire Coalfield has a low average seam methane content of 1.7m^3/tonne at a mean depth of 883 m, based on 43 samples from 8 boreholes (Creedy 1991). Values in the Thick Coal at Daw Mill Colliery are 2.5 m^3/tonne (Creedy 1983). These values are considered to be too low to form a viable CBM prospect.

26.1.9 South Derbyshire Coalfield

The South Derbyshire Coalfield has very low average seam methane values of 1.3 m^3/tonne at an average depth of 638 m, based on 36 samples from 5 boreholes (Creedy 1991). They are too low to be of interest as a CBM prospect.

26.1.10 Leicestershire Coalfield

There are no measurements of seam gas content published for the Leicestershire Coalfield. However, judging from adjacent coalfields and historical information, the values are likely to be very low. The coalfield has also been very heavily worked over the centuries. CBM prospects are considered to be very poor.

26.2 UNDERGROUND COAL GASIFICATION

Map 7b covers the area between the North Staffordshire Coalfield in the north, to the Shrewsbury coalfields in the west, to Leicestershire Coalfield in the east and the Warwickshire Coalfield in the south. On this map the outcropping coalfield areas do not form a UCG resource due to the extensive nature of former underground and the need to stand off from these workings, both vertically and horizontally. However, there is UCG potential in a number of areas on the map, particularly in the East and West Staffordshire areas and Warwickshire.

26.2.1 West Staffordshire

There is UCG potential in a number of areas covered by the map. In the southern part of the North Staffordshire Coalfield potential exists as a fringe around the southern extent of workings in the Stone area. In this area the Cockshead, Ten Feet, Yard, Hams, Ragman and Rowhurst meet the criteria for UCG, but not all these seams are continuously greater than 2m across the entire area. This area of good UCG potential may link with the Park Prospect to the south-east, although borehole information is lacking.

In the Park Prospect around Stafford a number of seams fulfill the thickness and depth criteria, including the Shallow, Wyrley Bottom, Park, Stinking, Benches, Eight Feet and Bass. Potential also exists to the south-west of Wolverhampton in the Staffordshire Thick Coal and the Fireclay. In other areas only localised UCG potential exists, centred on individual boreholes. An example of this is are the Lilleshall boreholes, north east of the Coalbrookdale Coalfield, where the Top and Double coals are in excess of 2 m locally. Ranton 1 borehole in the centre of the basin penetrates to 1.8 km and proves one coal with UCG potential.

Areas of unverifiable potential usually surround these good UCG zones. In this case they are marked as unverifiable due either to the absence of borehole information or to the lack of deep boreholes. It is known that there are deeply buried coals present in the central parts of the Stafford Basin and hence there may be further potential as yet unproven in this part of the basin.

Between the Codsall 1 and Bangley boreholes (west of Stafford) and the area south-west of Newcastle-under-Lyme the UCG resource is classified as poor. Here coals are present at depths suitable for UCG but they do not meet the thickness criteria (i.e. all are < 2m in thickness).

26.2.2 East Staffordshire

Conditions suitable for UCG are also present in the East Staffordshire prospect area. Two main areas exist, with a smaller third area also mapped. The main area, between Lichfield and Burton-on-Trent, is 84 km^2 in size and seams that meet the criteria include the Yard, Stockings, (Over & Nether) Main, Bottom Robins, Wyrley Bottom, Bass, Shallow, Deep and the Park. However, it should be stressed that not all seams meet the criteria across the entire area and the average thickness of coal per borehole meeting the criteria is 6.8 m.

In the area to the south east of Rugeley (25 km^2), between the Handsacre and Farewell boreholes, there is an average of 5.1 m of coal that meets the criteria, of which the more important seams are the Shallow, Bottom Robins and Yard. The third smaller area (c.29 km^2) is located on the north-east side of Birmingham, and coal has been proved in one borehole, Hamstead 1 Great Barr. There is up to 10 m of coal present in this borehole suitable for UCG in two seams, the Thick and the Benches coals.

26.2.3 Warwickshire Coalfield

The final area of interest on this map is in the Warwickshire Coalfield, south of the Daw Mill workings. Good UCG prospects occur in the Thick Coal in this area, where the seam varies from 3 to 6 m in thickness. This is also covered by Map 6.

26.3 CARBON DIOXIDE SEQUESTRATION

The most preferential area for CO_2 sequestration occurs at depths in excess of 1200 m. Coals are present at these depths across the West Staffordshire area (Stafford Basin), from Newcastle-under-Lyme to Stafford, covering an approximate area of 350 km^2. This area is in continuity with a suitable zone in the Cheshire Basin to the north-west. CO_2 sequestration may also be feasible as part of joint schemes in association with CBM and/or UCG. Areas of overlap between these latter two technologies occur to the south east of Newcastle-under-Lyme, where a good UCG zone intersects with CBM Area 1. This forms an area of approximately 43 km^2, which has the highest resource density of 292 m^3/m^2. On the west side of the Park Prospect there is another zone of overlap between a good UCG area and CBM Area 2, covering an approximate area of 30 km^2 with a resource density of 258 m^3/m^2. The other main overlap zone in the West Staffordshire area is associated with the Ranton 1 borehole and CBM Area 3 (15 km^2).

In the East Staffordshire area three good UCG areas have been mapped, although coals in this area have low methane contents (< 4 m^3/tonne) and hence these are not so attractive as CBM targets. North-east of Lichfield the overlap zone with CBM Area 5 covers an area of approximate 23 km^2 and the area to the south east of Lichfield overlapping with CBM Area 5 covers an area of approximately 57 km^2. The final area of good UCG, around the Hamstead 1 Great Barr borehole to the south, overlaps with CBM Area 6, and covers an area of 2.9 km^2.

27 MINING MAP 8a (Anglesey)

27.1 REVIEW OF COAL IN THE AREA

The Anglesey Coalfield comprises a narrow strip of Lower and Middle Coal Measures on the south west side of the island, The exposed coalfield covers an area of approximately 25 km^2, mostly under the wetlands of the Malltraeth Marsh. The Coal Measures are thought to be about 500 m in thickness (Glover et al. 1993), although boreholes only prove coal down to 358 m. There is thought to be about 200 m of Upper Carboniferous red mudstones and sandstones above the coal-bearing interval.

The Coal Measures rest unconformably on Dinantian limestone. The main structure within the coalfield is an asymmetrical, southwest-plunging syncline. A few faults are known but none are thought to have throws in excess of 30 m.

In the Anglesey Coalfield there are at least 8 proven seams (Figure 23). The borehole information indicates that only 3 seams are greater than 0.4 m in thickness. There is no information available on coal rank or methane content of these seams.

27.2 OPENCAST COAL MINING

In this coalfield borehole records are old and of poor quality but appear to show the first significant seam (i.e. >0.1 m in thickness) occurs at a depth of 70 m. This would indicate that the potential for opencast mining is this area is low. In addition to this, the area of outcropping Coal Measure mainly coincides with Malltraeth Marsh, which has wet meadow environments that are protected as Sites of Special Scientific Interest (SSSI) and an RSPB reserve.

27.3 UNDERGROUND COAL MINING

There are no working deep mines presently active in the Anglesey Coalfield. Mining is thought to have ceased in about 1875, with workings in the Yard seam known. The thickest seam proved is 0.7m in thickness (at a depth of c.270m). There is little potential for future large scale underground mining, as this would be limited by the size of the coalfield and the low thickness of coal.

27.4 COAL MINE METHANE

There is no coal mine methane resource in this area.

27.5 ABANDONED MINE METHANE

The majority of the mine workings are below sea level and keeping the mines dry during coal production was known to be difficult. The coalfield has not been worked since the late nineteenth century and mine water recovery is assumed to be complete. Therefore there are no AMM prospects.

28 NEW TECHNOLOGY MAP 8b (Anglesey)

28.1 COALBED METHANE

There is a limited amount of coal in the Anglesey Coalfield suitable for CBM extraction, with only one seam meeting the criteria. The seam methane content has not been measured but because the coalfield is relatively shallow, this is likely to be low. Taken together with the small size of the coalfield, this means that the potential for VCBM is extremely low.

28.2 UNDERGROUND COAL GASIFICATION

Boreholes in the Anglesey Coalfield do not penetrate deep enough to prove whether or not there is a UCG resource, with the deepest penetrating down to approximately 400 m. Hence the coalfield UCG resource is classified as unverifiable. However, it is considered unlikely that conditions suitable for UCG will be met in this area.

28.3 CARBON DIOXIDE SEQUESTRATION

Information is lacking about the presence of coals at depth so the potential for carbon dioxide sequestration is unknown. The potential for carbon dioxide sequestration in association with CBM or UCG is likely to be very poor, restricted by the likely very limited CBM potential and the unverifiable UCG potential in this coalfield.

29 MINING MAP 9a (North Wales)

29.1 REVIEW OF COAL IN THE AREA

The North Wales Coalfield forms a narrow belt of outcropping Coal Measures running from Point of Ayr in the north to Oswestry in the south, a distance of 61 km. The coalfield can be divided into:

- The Flintshire Coalfield in the north (approximately 125 km^2 in area), located between Point of Ayr and Caergwrle in the south,
- Denbighshire Coalfield (55 km^2 in area), separated from the Flintshire Coalfield by a narrow outcrop of Dinantian and Namurian strata, and
- The Oswestry Coalfield (30 km^2 in area), which is essentially a continuation of the Denbighshire Coalfield.

In addition to this, there is a concealed area of Coal Measures thought to be present in the Vale of Clwyd. However, not much is known about the subsurface geology of the Vale of Clwyd due to the lack of deep boreholes. The exposed Flintshire, Denbighshire and Oswestry coalfields comprise an area of approximately 400 km^2, with the Vale of Clwyd comprising a further c.200 km^2.

To the west of the North Wales Coalfield are rocks of Dinantian and Namurian age, whereas to the east the Coal Measures dip gently eastwards beneath younger Upper Coal Measures and Permian and Mesozoic strata. Upper Coal Measures are present at outcrop in the Denbighshire Coalfield, but to the north Permo-Triassic strata progressively unconformably overstep onto older Coal Measures such that Upper Coal Measures do not outcrop (Figure 24). At the Sealand 1 borehole, the Powell Coal (Figure 24) is present at a downhole depth of 57 m, indicating erosion of the Upper Coal Measures.

The main coal seams in this area occur within the Lower and Middle Coal Measures. The succession as a whole thickens northwards towards Point of Ayr and eastwards into the Cheshire Basin. This is associated with an increase in the thickness of coals towards the north and north-east. The coal rank is mainly medium-volatile coking coal. The rank increases towards the east under the Permo-Triassic cover rocks. The mean seam methane values for coals in the North Wales Coalfield are 7.1 m^3/tonne (Creedy 1991). The main seams of interest in the Flintshire Coalfield are the Five Yard or Main (2.75 m), Three Yard (3.58 m), Two Yard (3.04 m), Durbog (3.65 m), Stone (4.5 m), Hard Fivequarters (4.6 m) and the Bychton Two Yard (2.17 m) (Figure 24). In Denbighshire the thickest seams are the Upper Stinking (1.53 m), Powell (2.87 m), Two Yard & Crank (2 m), Quaker (1.9 m), Main (4 m), Nant & Lower Yard (2.71m) (Figure 24).

The coalfield is intensely faulted, with north-south trending faults dominant, although faults can often be slightly sinuous, with NW and NE trending elements. There is also an important set of WNW- ESE faults in this area, e.g. the Bala (Llanelidan) Fault System which divides the Flintshire from the Denbighshire Coalfield.

The Vale of Clwyd is a NW-SE trending half graben, with a major fault on its eastern side. NNW-SSE trending faults cut across it. Little is known about the coal-bearing strata, except that the Rhuddlan 1 CBM exploration borehole at the northern end of the Vale of Clwyd encountered approximately 4 m of coal in up to 4 seams >0.4 m thick.

29.2 OPENCAST COAL MINING

There are opportunities for opencast mining in the North Wales Coalfield. In the north, the Flintshire Coalfield forms a fringe of Coal Measures that flanks the coastline There is potential for opencast mining here, although the outcrop area locally forms steep slopes down to the coast and hence parts may not be suitable. Further south, the area between Mold and Connah's Quay is much larger and there would theoretically be better opportunities for opencast sites. In the Denbighshire and Oswestry coalfields there is probably more potential for opencast mining because the area is more rural. There are no opportunities for opencast mining in the Vale of Clwyd.

29.3 UNDERGROUND COAL MINING

Coal was first worked in the North Wales Coalfield in the 16th century and, by the mid 17th century coal was exported to Ireland from Flintshire. In the coalfield's heyday, there were 38 collieries employing over 12,000 men and the coalfield reached peak production of 3.5 million tons in 1913. In the 20th century the Shotton steelworks used coal from Bersham Colliery. However, Bersham suffered from problems, including faulting, thin seams and ingress of mine water. This was the last working colliery in the Denbighshire Coalfield, closing in 1986.

The Point of Ayr Colliery, near Prestatyn in Clwyd, was the last working coal mine in North Wales. Situated on a reclaimed headland near the mouth of the river Dee estuary, the mine was originally sunk in the 1880's and most of the workings extended out under the estuary of the River Dee. Traditional pillar & stall methods were used until 1960 when the first longwall face was introduced, pillar & stall being finally phased out in 1967. The mine worked the Five Yard (Main), Three Yard, Two Yard, Durbog (Upper Red), Stone, Hard Fivequarters and the Bychton Two Yard. It closed in 1996.

The North and South Dee prospects were investigated as part of the NCB Plan 2000 phase of exploration and potential exists in these areas for new deep mines. In the North Dee prospect Blacon borehole, there are 6 coals >1 m in thickness, the most important being the Two Yard (2.86 m), Main (3.11 m) and Nant (2.07 m). In the South Dee prospect, Trevalyn borehole, there are 9 seams >1 m in thickness, the most important being the Lower Stinking (3.44 m at 1089 m), Main (2.72 m at 1224 m) and the Nant (1.89 m at 1309 m). Further south, in the Dudleston borehole, the Quaker and Main combine to form one seam 4.14 m in thickness at 726 m depth. Hence there is good potential for underground mining along the north-south length of the North Wales Coalfield in areas downdip of former workings.

29.4 COAL MINE METHANE

All the mines in this area are now closed so there is no potential for CMM.

29.5 ABANDONED MINE METHANE

The Flintshire Coalfield was worked for many centuries before the closure of the last colliery, Point of Ayr, in 1996. This was known as a gassy pit and a methane drainage scheme was in operation during the life of the colliery (Lane 1987). Lane (1987) records that some seams were more gassy than others, with the Three Yard characterised by particularly high rates of methane seapage. However, a plan was developed to flood the offshore workings of Point of Ayr Colliery (Younger 1996) and this has been carried out (P. Younger, pers. comm., 2003). Elsewhere in the coalfield mine water pumping has long ceased and a number of emissions have been reported. Hence mine water recovery in the remainder of the Flintshire Coalfield is thought to be well advanced or complete.

In the Denbighshire Coalfield numerous shallow mine workings and mine entries are present and these are likely to form many discrete blocks of connected workings in which mine water pumping has long since ceased. During the working life of Bersham Colliery, a methane drainage system was in place, using five vacuum pumps at surface to extract methane from the workings. Up until 1978, the methane was released into the atmosphere but then it was sold to a local brickworks to fire their tile kilns. This was supplied via a 2 mile underground pipeline. Up to 31.7 x 10^{10} kJ (3 million therms) of gas per year were supplied, equal to around 13,000 tonnes of coal (see http://www.ap.pwp.blueyonder.co.uk/bcthis.htm). In theory then Bersham Colliery should form an AMM prospect and a well, Bersham 1 has been drilled by Evergreen. However, the colliery was known to have problems with mine water and pumped some 70 million gallons per year.

Surface emissions of water have been reported to the west of Gresford Colliery. In view of the date of closure of the mines in this area, the quantities of water pumped, and the known surface emissions, it is thought that mine water recovery is complete in the west and well advanced in the east.

Further south, Ifton Colliery, which closed in 1968, was reported to be connected to the Black Park and Brynkinallt workings. Water recovery at Black Park is thought to be complete, which suggests that water levels in all these collieries are recovered. No information is available on water levels in the mines in the Oswestry Coalfield. However, the last mine, New Trefonen, closed in 1891, so water levels in the mine workings are assumed to be fully recovered.

Thus, despite the high initial seam gas contents known from this coalfield, AMM prospects are considered to be poor throughout the North Wales Coalfield.

30 NEW TECHNOLOGY MAP 9b (North Wales)

30.1 COALBED METHANE

30.1.1 Vale of Clwyd

The Rhuddlan 1 CBM exploration borehole in the Vale of Clwyd encountered approximately 4 m of coal in up to 4 seams >0.4 m thick. However, the borehole did not produce commercial gas flows, severely downgrading the prospectivity of the Vale of Clwyd.

30.1.2 Flintshire Coalfield

The Point of Ayr Colliery (closed 1996) was one of the very few places in the UK where significant gas flows were established from boreholes (Dunmore 1969, Creedy 1994). The mine is in CBM Area 1 of Map 9B, which is thought to have the best CBM prospectivity in this area. Potential is probably mainly in the offshore area and would obviously have to be away from the former mine workings, which have now flooded.

The down dip continuation of the Flintshire Coalfield (CBM areas 2 and 4) has a good resource base for coalbed methane production. Average values of 8.25 m^3/tonne methane plus ethane are found in the North Dee prospect (Creedy 1983).

30.1.3 Denbighshire and Oswestry coalfields

The down dip continuation of the Denbighshire and Oswestry coalfields (CBM Area 3) has significant seam methane content where measured in the north of the Denbighshire Coalfield, and a good resource base for CBM production. The Oswestry area probably has less CBM potential than the Denbighshire Coalfield because it has fewer thick seams. There are no seam gas content measurements from the Oswestry Coalfield.

Since 1993, nine CBM wells have been drilled in this area by US company Evergreen Resources. These are: Erbistock 2 & 3, Kemira 1, Rhuddlan 1 and Sealand 1-5. No results have been made available although none of the wells went into production so it is assumed that they were not successful. These wells were drilled into areas with some of the best resource bases for CBM in the country. It is known that some of the wells were stimulated by fraccing to try and improve flow rates. One possible explanation for the lack of success is that coal seam permeability is low.

30.2 UNDERGROUND COAL GASIFICATION

Large areas exist on this map that are suitable for UCG. This is particularly the case in the deeper parts of the Denbighshire and Flintshire coalfields, east of the area of former underground mining activities. The main area with good UCG potential can be traced from north of Oswestry (South Dee), forming a NNE belt that runs for 62 km to Widnes in the southern part of the South Lancashire Coalfield. This area continues north-eastwards onto Map 10 and covers an area of approximately 397 km^2. The average thickness of coal that meets the requirement for UCG in this area is 8.2 m (Table 7). In the South Dee area the Quaker & Main, Two Yard, Crank and Ruabon Yard are suitable coals for gasification. It must be stressed though that not all these seams meet the criteria in all boreholes. A separate area, 63 km^2 in size, occurs just west of Chester (North Dee area). In the North Dee area the Wall & Bench seam meets the criteria for UCG and the average thickness of coal that meets the requirement is 3.3 m (Table 7).

Between these two good UCG areas the Coal Measures lie at depths greater than 1200 m and hence are too deep to be considered as a resource. In other areas information, in the form of borehole data, tends to be lacking and hence the resource is mapped as unverifiable. In the Vale of Clwyd the resource potential is not known, except in the Rhuddlan borehole at the northern end of the Vale, where there are no seams greater than 2 m thick. Resources may be present in the near offshore area, although deep borehole information is lacking. The Hoyle Bank Borehole, in the Dee Estuary, proves 6 seams greater than 2 m in thickness, but these occur at depths above 600 m. However, there may be potential further offshore where the Coal Measures are known to be more deeply buried. Large areas of the Wirral may have potential as an extension to the known area of UCG potential in South Lancashire but again there are no boreholes so information is lacking. Around the city of Chester, coals are deeply buried (>1200m) and hence are not considered as a UCG resource.

30.3 CARBON DIOXIDE SEQUESTRATION

The Coal Measures along the eastern edge of Map 9b occur at depths in excess of 1200 m and hence would meet the main criteria for CO_2 sequestration. On this map this zone covers an area of approximately 885 km^2, although it continues eastwards into the Cheshire Basin and in total covers an area of about 2600 km^2. Carbon dioxide sequestration may also be feasible in areas where there are zones of overlap between the technologies and a combined scheme may be possible in such areas. There is clear overlap between a good UCG area and the zone suitable for CO_2 sequestration along the western margins of the 1200 m line (south east of Ellesmere Port). In addition, CBM areas 3 and 4 also overlap with good UCG areas. Thus there may also be good prospects for a combined UCG-CBM scheme in association with CO_2 sequestration across large areas of this map.

31 MINING MAP 10a (North Staffordshire, South Lancashire & Burnley area)

31.1 REVIEW OF COAL IN THE AREA

31.1.1 Burnley Coalfield

The Burnley Coalfield forms an area of 300 km^2 of outcropping Coal Measures centred on the town of Burnley. The main coal-bearing interval is the Lower Coal Measures, which is up to 650 m thick. The lower part of the Middle Coal Measures is also thought to be present. Much of the coalfield is overlain by thick superficial drift deposits and there is much urban development. The coalfield has been extensively worked for coal over a long period of time.

The more important seams in terms of mining are the Burnley Four Foot (Trencherbone), Arley, and Lower and Upper Mountain seams (Figure 25). Coals are medium to low volatile and there are no published seam methane data.

The Burnley Coalfield is situated in the core of a north-east trending syncline. It has steep dips on its north-western side and more gentle ones of its south-eastern side. This main structure is cut by a series of normal faults trending NW-SE. To the north of the main syncline is the Pendle Anticline and to the south is the NE-SW trending Rossendale Anticline, along which older Namurian strata outcrop.

31.1.2 South Lancashire Coalfield

The South Lancashire Coalfield crops out across an area of approximately 970 km^2, stretching from Rochdale in the east to St Helens in the west. A spur runs southwards from Rochdale to just south of Stockport. In the east and north older Namurian strata are present at outcrop and to the west and south the Coal Measures are unconformably overlain by Permo-Triassic strata. To the west, the Coal Measures continue below Liverpool and the Wirral to join up with the North Wales Coalfield. To the south, the coalfield deepens significantly beneath Permo-Triassic strata and passes into the Cheshire Basin. A substantial portion of the coalfield is covered by urban development.

Coals are mainly present within the Lower and Middle Coal Measures, with a few additional coals in the lower part of the Upper Coal Measures (Figure 26). The main coal-bearing interval typically varies from about 590 m in the west to 880 m in the east. The lower part of the Lower Coal Measures, below the Arley seam, typically contains coals that are thin and of variable quality. The rest of the Lower Coal Measures and Middle Coal Measures form the most important coal-bearing interval, with a number of coals in excess of 2 m in thickness, including the Park Yard, Crombouke, Roger, Earth Delf, Rams (Ince Six Foot), Higher Florida, Doe, Wigan Five Feet, Wigan Four Feet, Trencherbone, Plodder and King & Queen (Figure 26). Coals from the Upper Coal Measures are generally thin, the exception being the Worsley Four Foot, which can be up to 1.6 m in thickness. Methane contents for the coalfield are high; Creedy (1991) records an average adsorbed methane value of 8.2 m^3/tonne. Coal rank ranges from high to medium volatile.

31.1.3 Cheshire Basin

The Cheshire Basin is one the largest British onshore post-Variscan rift basins and is over 100 km long, has a width of about 55 km and covers an area of 3500 km^2 (Plant et al. 1999). Coal-bearing Carboniferous strata are present in the basin, deeply buried below Permo-Triassic rocks. For the purposes of this study, the Cheshire Basin area is defined as the area across which Coal Measures are present at depths in excess of 1200 m from the surface. To the west, north and east the North Wales, South Lancashire, North Staffordshire and Shrewsbury coalfields surround it. Consequently it is likely that Coal Measures are present beneath almost the entire basin. However, only two boreholes have actually proved Carboniferous strata. The Prees Borehole [5572 3344] proved reddened Carboniferous at c.3610 m with Lower Palaeozoic rocks at c. 3850 m below Kelly Bushing (KB). In the Knutsford No.1 borehole [7027 7785], 45 km to the NNE, Westphalian aged rocks, including coals, were proved at a depth of below c. 2820 m KB to the total depth at 3045.7 m KB (Plant et al. 1999). In the centre of the basin, just east of Crewe, seismically derived contours put the base of the Permo-Triassic at depths of between 3500-4500 m (Plant et al. 1999, Fig 36).

The eastern and south-eastern margins of the basin are defined by the NE-SW trending Wem-Bridgemere-Red Rock fault system. The main structures within the basin are faults. In the south-east and south-west, faults trend NE-SW parallel to the main basin bounding faults. On the north-western flanks of the basin faults trend north-south and in the north and north-east, faults trend N-S and NW-SE (Plant et al. 1999).

There are no coal seam methane measurements in the main part of the Cheshire Basin and gas content has been estimated from values in the adjacent North Wales, South Lancashire and North Staffordshire coalfields.

31.1.4 North Staffordshire Coalfield

The exposed part of the North Staffordshire Coalfield covers an area of approximately 250 km^2 and forms a triangular shaped outcrop centred on the town of Stoke-on-Trent. The southern edge of the exposed coalfield is irregular in shape and the Coal Measures form a syncline (the Potteries Syncline), which plunges southwest beneath Permo-Triassic strata. The Swynnerton Fault is conventionally taken as the boundary between the North Staffordshire Coalfield and the East and West Staffordshire areas. To the west, the coalfield is bounded by the Red Rock Fault against the Triassic, while the eastern flank is formed by the outcrop of the underlying Namurian along the axis of the Werrington Anticline. In the south and along the axis of the Potteries Syncline red beds of the Etruria Formation overlie the Coal Measures. This contact is diachronous, such that in the exposed coalfield it occurs about 15 m above the uppermost widely worked seam in the Upper Coal Measures, the Blackband Coal, and further south it occurs towards the top of the Middle Coal Measures.

There is evidence for thickness changes in the Coal Measures in this coalfield, attributable to tectonic control on the deposition and, in some case, erosion of the succession (MacCarthy et al. 1996). The thickest Coal Measures occur in the Potteries Syncline, which is located just west of Newcastle-under-Lyme (MacCarthy et al. 1996). To the north-west, on the axis of the Western Anticline, the Upper and Middle Coal Measures have been removed by erosion (MacCarthy et al. 1996). Corfield (1991) has demonstrated that coals amalgamate and thicken over the Western Anticline, indicating that folding was contemporaneous with sedimentation, linked to NW-SE compression.

Coals are present throughout the Lower to Upper Coal Measures (Wilson et al. 1992). Over 40 seams have been worked in a 2,000 m thick Coal Measures sequence, with the Great Row, New Mine, Banbury, Cockshead, Two Row, Ten Feet and Rowhurst being over 2 m in thickness (Figure 27). The coal rank increases into the axis of the Potteries Syncline. In the high rank area the Moss seam has a volatile content of less than 37% (high-volatile A bituminous) increasing to more than 40% (high-volatile B bituminous) on the flanks of the syncline (MacCarthy et al. 1996). Rank has also been shown to increase with depth.

MacCarthy et al. (1996) have calculated the net coal thickness and total number of coals in part of the North Staffordshire Coalfield. Thickness contours have a NW-SE trend and clearly thicken into the

Potteries Syncline up to a maximum of 40 m. The maximum number of coals (c.35) occurs, the largest proportion of these are from the Middle Coal Measures.

31.1.5 Cheadle Coalfield

To the east of the North Staffordshire Coalfield is the Cheadle Coalfield, 45 km^2 in area. This includes the Shaffalong Coalfield, on the north-west flank of the Cheadle Coalfield; this is a small, north-south oriented coalfield, 6 x 1 km in size. These coalfields have been preserved in the Cheadle and Shaffalong synclines, on either side of the Overmoor Anticline (Chisholm et al. 1988). Coal Measures continue to the south of the Cheadle Coalfield, concealed under Permo-Triassic rocks. There is only a very thin covering of superficial drift in this coalfield (Chisholm et al. 1988).

Coals belonging to the Lower Coal Measures and basal part of the Middle Coal Measures are present (Chisholm et al. 1988). The main seams are the Two Yard, Yard, Four Foot, Dilhorne, Alecs, and Woodhead, all of which are greater than 1 m in thickness (Figure 28). There are no coals greater than 2 m in thickness.

The main structure within the Cheadle Coalfield is the Cheadle Syncline, whose axis runs approximately NNE-SSW. This is cross cut by a series of normal faults, trending east-west, NNW-SSE and NNE-SSW (Chisholm et al. 1988).

31.2 OPENCAST COAL MINING

31.2.1 Burnley Coalfield

There are thick drift deposits in this coalfield, particularly in the west, so this reduces the opportunities for opencast sites. There is some potential in the east of the coalfield though, and previous sites are known in this area.

31.2.2 South Lancashire Coalfield

As of April 2002, there was one opencast site in this coalfield (source: DTI web site), although there is potential for further opencast mining over large parts of this coalfield. However, this is reduced by a number of factors. Firstly the basal part of the Lower Coal Measures does not contain many thick seams. Hence areas on the northern and north-western flank of the coalfield are probably not economically viable. Secondly there are thick drift deposits (up to 50 m in places) across the coalfield and, thirdly, much of the area is urban or industrialised. All of the above factors will reduce the opportunities for opencast mining and hence site specific studies will be required to identify suitable areas.

31.2.3 Cheshire Basin

The is no potential for opencast mining in the Cheshire Basin as all the Coal Measures are buried beneath Permo-Triassic cover at depths in excess of 1200 m.

31.2.4 North Staffordshire Coalfield

Opportunities for opencast mining occur in the North Staffordshire Coalfield, but are restricted to the western, northern and eastern flanks of the coalfield, where the Lower and Middle Coal Measures come to crop on the flanks of the Potteries Syncline. In the core of the syncline are reddened Upper Coal Measures that lack coals. The North Staffordshire Coalfield only has a thin drift covering so this would not restrict opportunities. However, much of the coalfield is urban or industrialised and this has an impact on the potential for opencast mining.

31.2.5 Cheadle Coalfield

Opencast mining has taken place in this coalfield, and was common in the immediate post-war years (Chisholm et al. 1998). There is still some remaining potential but this might be affected by the presence of extensive shallow coal workings in this area.

31.3 UNDERGROUND COAL MINING

31.3.1 Burnley Coalfield

The Burnley Coalfield has been extensively worked; the last deep mine, Hapton Valley Colliery, closed in 1981. The extensive mining and the lack of good, thick seams mean that there is no potential for major underground mining in this coalfield.

31.3.2 South Lancashire Coalfield

Currently there are no deep mines in operation in this area, with the last mine in the South Lancashire Coalfield, Parkside, closing in 1993. A large area of coal (approximately 240 km^2 in size) suitable for deep mining (i.e. <1200m depth) forms a fringe of unworked Coal Measures that lie to the south of old workings, between Widnes, Warrington and Salford. In this area the Crombouke, Rams, St Helens Yard, Higher Florida, Doe, Wigan Five Foot, Wigan Four Foot, Wigan Two Foot, Trencherbone, Plodder and London Delf seams are all, in places, greater than 2 m in thickness.

31.3.3 Cheshire Basin

The is no potential for deep mining in the Cheshire Basin as all the Coal Measures are buried beneath Permo-Triassic cover at depths in excess of 1200 m.

31.3.4 North Staffordshire Coalfield

There are early references to underground mining in this coalfield from the 11th century onwards (e.g. at Tunstall, Shelton and Keele). These early workings were shallow operations from bell pits and shallow shafts. By the beginning of the 20th century, mine shafts down to depths of 823 m were being sunk (e.g. Stafford Colliery) to work coal. The last two pits in the North Staffordshire Coalfield, the Hem Heath-Trentham complex and Silverdale, closed in 1996 and 1998 respectively. Between them, these mines worked the Bassey Mine, Great Row, Cannel Row, Winghay, Burnwood, Moss, Yard/Ragman, Bowling Alley and Holly Lane seams.

Prospects for future underground mining operations exist to the south of the former workings, e.g. the Park Prospect, between the North and South Staffordshire coalfields (see above, Section 25.3.5). Another suitable area occurs to the south west of former Hem Heath-Trentham workings. Boreholes prove that the Burnwood, Rowhurst, Ragman, and Ten Feet seams are in excess of 2 m in thickness in this area. Further south, borehole data is lacking. To the south west of the former Silverdale workings the potential appears quite limited because coals tend to be quite thin.

31.3.5 Cheadle Coalfield

Underground mining in the Cheadle Coalfield has taken place over many centuries, but due to the size of the coalfield, and the thinner and fewer seams compared to the North Staffordshire Coalfield, it never reached the same level of importance. Production reached 200,000 tons per year in 1875 but deep coal mining in the area ended with the closure of Foxfield Colliery in 1965.

Chisholm et al. (1988) speculate that there may be potential for future underground mining to the south-west of the former workings, in the area south of the Callowhill Fault. Unfortunately good borehole information is lacking from that area.

31.4 COAL MINE METHANE

All the mines in the area covered by Map 10 have now closed so there is no potential for CMM.

31.5 ABANDONED MINE METHANE

31.5.1 Burnley Coalfield

Mine water levels in the Burnley Coalfield are thought to be substantially recovered. Thus AMM prospects may be poor unless dry mine workings can be identified. Initial seam gas contents have not been published.

31.5.2 South Lancashire Coalfield

Lancashire has a complex mine water recovery history. Initial average seam gas contents are high, at 8.2 m^3/tonne methane plus 1.28 m^3/tonne ethane at an average depth of 1098 m (Creedy 1991). Hence if dry workings can be identified, they should be productive and there is excellent AMM potential. Ongoing investigations by the Coal Authority indicate that 48 mine water surface emissions have been recorded in this coalfield. Mine water recovery is thought to be complete or well advanced over most of the coalfield, the exceptions being mainly in the south-western, deeper, recently worked areas, where significant AMM opportunities may occur. Formerly, Parkside Colliery collected methane via a methane drainage scheme and sold it to a Warrington factory (Plant et al. 1999, p.224). This represents an area with potential for AMM. Other potential areas to the north-east and south-west of Parkside Colliery are also worthy of further investigation.

31.5.3 Cheshire Basin

There are no AMM prospects in the Cheshire Basin.

31.5.4 North Staffordshire Coalfield

The coalfield is likely to have variable AMM prospects, depending on the state of mine water recovery. Whilst the former Wolstanton Colliery was open, methane from the mine was collected via a methane drainage scheme and sold to local pottery manufacturers (Plant et al. 1999, p.224). In theory, this should make a good AMM prospect. However, it is known that mine water in the north-east, north-west and along the western fringes (including the Wolstanton, Chatterley Whitfield and Victoria collieries) is probably largely recovered and hence this area is likely to have only limited AMM resources. Mine water recovery is also well advanced in the Berry Hill area, although methane emissions have been recorded at Bentilee [SJ910 460], indicating that the area has not fully recovered (Wardell Armstrong 2000d).

The more modern workings to the south (including the Silverdale, Trentham-Hem Heath and Florence mines) are still recovering and would form better AMM prospects. The only exception to this is the deeper workings associated with Holditch Colliery, which have probably recovered. The former Hem Heath and Florence mines were connected as part of the Trentham complex and, on abandonment, connections were left open (Wardell Armstrong 2000d). Underground connections previously existed between Stafford and Hem Heath and between Parkhall and Florence; dams were constructed to isolate Florence and Hem Heath from the older workings to the north (Wardell Armstrong 2000d). No significant water was recorded entering the 2 collieries prior to abandonment in 1992 and 1996, suggesting these dams were effective. A mine water and gas monitoring facility currently exists at Hem Heath shaft (Wardell Armstrong 2000d). Hence it is likely that there is a large reservoir for recovery in this area and AMM prospects are good.

At the former Silverdale Colliery pumping has continued from Shaft 17 since closure in 1998 and mine water recovery in being controlled by this pumping (Wardell Armstrong 2000c). In 1999, water levels in the shaft were maintained at about 35 m below OD, with a pumping rate of approximately 1,300 m^3/day (Wardell Armstrong 2000d). Hence it is likely that this area is largely unrecovered. Mine gas emissions have been recorded at the Parkside housing estate near to the colliery and monitoring is now in place. In January 1999, PermaGas, a subsidiary of StrataGas, began to extract methane from the one of the drifts of Silverdale Colliery, which it now supplies to Octagon Energy's North Staffs Gas Grid. StrataGas has supplied more than 63.3 x 10^{10} kJ (6 million therms) of gas to Octagon who have delivered this gas to local industry (http://www.stratagas.com/project2.html).

31.5.5 Cheadle Coalfield

The most recent mine in the Cheadle Coalfield (Foxfield Colliery) closed in the 1960s indicating that mine water in this area is likely to have recovered and hence AMM prospects are low.

32 NEW TECHNOLOGY MAP 10b (North Staffordshire, South Lancashire & Burnley area)

32.1 COALBED METHANE

32.1.1 Burnley Coalfield

The limited thickness of coal seams in the Burnley Coalfield, plus the fact that they are generally not deeply buried, means that this coalfield has poor CBM prospects.

32.1.2 South Lancashire Coalfield

The South Lancashire Coalfield has a good resource base for CBM production. The average seam methane content was 8.2 m^3/tonne, based on 327 samples from 22 boreholes at an average depth of 1098 m (Creedy 1991). The area on the southern fringe of the coalfield, down to the 1200 m line, is ranked as the best potential area for CBM on this map (CBM Area 1). Two VCBM exploration wells have been drilled in his area; Fouroak 1 and Kemira 1. Neither of these wells has gone into commercial production, indicating that the CBM prospectivity is not as high as would be anticipated.

32.1.3 Cheshire Basin

The coals in this area are all below 1200 m depth and may reach depths of 4 km in the basin centre. There are no boreholes that penetrate the productive Coal Measures succession in this area. Thus the seam methane content and total thickness of coal are not known. However, by analogy with surrounding areas they are likely to be high. Thus the area may well have a fair resource base although any permeability in the seams is likely to be very limited at these depths.

32.1.4 North Staffordshire Coalfield

This study shows that the North Staffordshire Coalfield has good potential for CBM production. The average seam methane content is 7.1 m^3/tonne, based on 466 samples from 17 boreholes (Creedy 1991). Values in the Hobgoblin borehole range up to 10.34 m^3/tonne (Creedy 1986). The *in situ* permeability of the Great Row seam was estimated as 0.1-0.5 millidarcies, suggesting that if the other seams have similar permeabilities, it will prove difficult to establish commercial CBM production. High gas contents and total thickness of coal meeting the criteria indicate an excellent CBM resource base over much of the area (CBM areas 2 and 3), although to the south-west (CBM areas 7 and 9) methane contents decrease, resulting in a reduction in the resource density.

The CBM potential of part of the North Staffordshire Coalfield has also been described by MacCarthy et al. (1996). They estimate that there is 5.6×10^{10} m^3 of gas in place, across their study area of 600 km^2. This was calculated for coals greater than 0.3 m in thickness, present at depths less than 1500 m with over 200 m of Carboniferous overburden (MacCarthy et al. 1996). Gas content and initial gas-in-place are highest in the north, coincident with the occurrence of thick, high rank coals (MacCarthy et al. 1996).

Although there have been no CBM wells drilled in the area, there have been proposals put forward. For example, the Coal Authority applied to carry out a UCG-CBM pilot study at Silverdale site (Wardell Armstrong 2000c). Part of this proposal included a plan to carry out enhanced CBM and CO_2 sequestration trials. The seams of interest were the Ten Foot (2.6 m), Banbury (2.1 m), Cockshead (1.8 m) and the Bullhurst (3.0 m). However, planning permission for this trial was not granted.

Stratagas recently applied for planning permission carry out the Swallowcroft coalbed methane pilot project near Seabridge, Newcastle-Under-Lyme. This is was to be a four well CBM Pilot project, located on PEDL 056, and was intended to last approximately two years. Its purpose was to assess the potential for commercial production of CBM from coal seams. However, planning permission was not granted and Stratagas have decided not to appeal against this decision.

32.1.5 Cheadle Coalfield

Coals in the Cheadle Coalfield tend to be thin and they are generally not deeply buried. Hence this coalfield has poor CBM prospects.

32.2 UNDERGROUND COAL GASIFICATION

This map shows that the good UCG prospect identified from North Wales (Map 9) extends into the South Lancashire Coalfield. The area with coals suitable for UCG in South Lancashire covers an area of 105 km^2 fringing the western and northern margins of the Cheshire Basin. In the South Lancashire Coalfield the northern limit to this area of good UCG potential is the extent of former underground coal workings; the southern limit is the 1200 m line on the top of the Coal Measures. In South

Lancashire the London Delf, Crombouke, Rams, Higher Florida, Lower Florida, Doe, Wigan Four Foot, Trencherbone and Plodder all locally meet the criteria for UCG. The average thickness of coal suitable for gasification is 8.2 m per borehole, although exceptionally up to 18 m of coal is present in the Birchwood Borehole.

Between Manchester and Stockport it is thought that coals occur at suitable depths for UCG but deep borehole coverage is generally lacking, hence the presence of a resource could not be verified. In the area immediately to the north west of the North Staffordshire Coalfield coal-bearing strata are present but are too deep to form a UCG prospect; these are deeply buried in the Cheshire Basin. Coals are present between 600-1200 m in the area to the south west of Newcastle-under-Lyme but they do not meet the required thickness to be suitable for UCG. Good UCG prospects also occur along the southern fringe of the North Staffordshire Coalfield, as described for Map 7.

There are no areas where the Coal Measures are deep enough to be suitable for UCG in either the Burnley or the Cheadle coalfields.

32.3 CARBON DIOXIDE SEQUESTRATION

Coal Measures occur at depths greater than 1200 m across a wide area of the southern end of the South Lancashire Coalfield and across most of the Cheshire Basin area. Hence there is theoretical potential for carbon dioxide (CO_2) sequestration across a large area of this map. This area of deeply buried Coal Measures continues just to the south of the exposed North Staffordshire Coalfield in a belt that persists to Stafford. Carbon dioxide sequestration may also be feasible across all areas where CBM and UCG can take place. The best location for such a scheme would occur where there are good prospects for UCG and a correspondingly high methane content. Such areas are present along the southern edge of both the South Lancashire and the North Staffordshire coalfields.

33 MINING MAP 11a (Nottinghamshire)

33.1 REVIEW OF COAL IN THE AREA

The area covered by this map is the southern half of the vast coalfield that lies beneath much of eastern England, east of the Pennines. From its outcrop, which runs roughly from Nottingham to Bradford and Leeds via Chesterfield, Sheffield and Barnsley, it dips eastwards beneath younger rocks, forming a thick and continuous sheet of concealed Coal Measures that reaches the coast between Bridlington in the north and Skegness in the south. From there it continues eastwards beneath the southern North Sea.

The best coal seams occur in the Lower and Middle Coal Measures. The most valuable and widely extracted seam is the Top Hard (= Barnsley) coal (Figure 29). Cumulative coal thickness in seams >0.4 m is commonly between 19 and 22 m and there are commonly several seams >2 m in thickness in most areas away from the coalfield margins. East of the N. E. Leicestershire, Till and Witham mining prospects, detailed information on coal seam thickness is not available because there are no continuously cored boreholes. However, information from oil and gas exploration wells suggests that the vast coal resources formerly present in the mined areas, and found in the mining prospects, continue all the way to the coast.

33.2 Opencast Coal Mining

There has been extensive opencast mining in the past, as shown by the density of abandoned sites. As of April 2002 there were 5 working opencast sites in this coalfield (Source: DTI web site). Active licences are particularly dense east of Chesterfield. There is still considerable potential in this coalfield. Such activities might be considered attractive where the presence of opencast sites would result in reclaiming former colliery land.

33.3 Underground Coal Mining

This coalfield has been extensively and intensively exploited for hundreds of years, particularly since the industrial revolution. Over the centuries mining has gradually advanced to the east. At its maximum, the Nottinghamshire Coalfield produced in excess of 25 million tons of coal in a year and more than half of the county's pits produced more than 1 million tons a year. Although mining has declined from its peak, three of the UK's largest mines occur in this area. From north to south these are: Harworth, Welbeck and Thoresby. All the mines south of Thoresby, near Edwinstowe, are now closed.

Three major underground mining prospects explored by British Coal occur in the area covered by the map: the Till, Witham and North East Leicestershire prospects. The North East Leicestershire prospect was partially developed as the Asfordby mine until this was forced to close due to adverse geological conditions.

33.4 Coal Mine Methane

All the active mines in this area drain methane. Electricity is generated from CMM at Harworth in a 14 MWe combined cycle system, at Thoresby (2.8 MWe power generation), Maltby (4.2 MWe) and Welbeck (2.8 MWe).

33.5 Abandoned Mine Methane

Most of the mines in Nottinghamshire and Derbyshire are connected underground. Mine water recovery is controlled to some extent by pumping to protect the remaining working mines in North Nottinghamshire. Mine water recovery has started to the south of the working mines of Thoresby and Welbeck and recovery is probably complete in the older, shallower workings along the western side of the coalfield. However, the former Bevercotes Colliery, the most southerly pits in Nottinghamshire (Cotgrave, Clifton and Gedling) and Asfordby in the Vale of Belvoir, are not connected to the main area of mining in Nottinghamshire and their mine water recovery status is unknown, although predictions could be made using water inflow data gathered during mining.

AMM projects have been initiated at Bentinck, Markham, Shirebrook and Steetley collieries, indicating excellent potential. However, the Steetley site has now ceased operation due to operational difficulties and poor economics, and Shirebrook production is running at about 50 % of its original output (see section 8.1.3 for further details). Other AMM prospects may also be present in this coalfield. For example the New Hucknall Colliery at Huthwaite south west of Mansfield [447270 358370] was known to be a gassy mine and, in 1983, up to 100 million litres of pure methane were drawn off each week (http://www.healeyhero.fsnet.co.uk/rescue/pictures/pits/hucknall.htm).

It should be noted that Alkane Energy have recently suspended development of further AMM sites in the UK because falling electricity prices and the failure of AMM to qualify as Renewable Energy have meant that their electricity generating operations are not financially viable.

Due to the complexity of mining in this coalfield the AMM prospects are extremely variable. Along the western flank, mine water recovery is likely to be complete in the old, shallow workings; thus AMM prospects are likely to be poor. In the east, where the workings are more modern and groundwater is being controlled by pumping, prospects for AMM are likely to be good. In the combined Nottinghamshire and Yorkshire coalfields (Maps 11 and 12) this good AMM region covers an approximate area of 666 km^2. Inbetween these two areas the AMM prospects have been mapped as variable and potential may exist but further exploratory work will be required on a site specific basis. In the combined Nottinghamshire and Yorkshire coalfields (Maps 11 and 12) this variable zone covers an approximate area of 1508 km^2.

34 NEW TECHNOLOGY MAP 11b (Nottinghamshire)

34.1 COALBED METHANE

34.1.1 N E Leicestershire

The north-east Leicestershire area comprises the Vale of Belvoir Coalfield and surrounding areas. The very low seam methane measurements (average of 68 samples from 13 boreholes is 0.5 m^3/tonne, Creedy 1991) indicate that this area has no potential for VCBM production.

34.1.2 Nottinghamshire/Derbyshire/South Yorkshire/South Lincolnshire

The CBM prospects of the Nottinghamshire/Derbyshire area of the East Pennine Coalfield are poor because of relatively low seam gas contents and uncertainty over the permeability of the coals. This is reflected in the complete absence of VCBM exploration boreholes. Average seam gas content measurements are 4.6 m^3/tonne in North Nottinghamshire based on 915 samples from 70 boreholes, 4.6 m^3/tonne in the Till prospect based on 222 samples from 13 boreholes, 1.6 m^3/tonne in South Nottinghamshire based on 116 samples from 14 boreholes and 1.5 m^3/tonne in the Witham prospect, based on 407 samples from 50 boreholes (Creedy 1991). East of the Witham and Till prospects, there are no seam gas content measurements and an estimated average seam methane content of 5 m^3/tonne has been used for the resource calculation.

34.2 UNDERGROUND COAL GASIFICATION

There are large areas on this map that meet the criteria for UCG. The best areas occur mainly between Newark and East Retford and extend to the north west of Gainsborough onto Map 12. Further south, i.e. north-east and south-east of Nottingham, good potential also exists but tends to be patchy and isolated, surrounded by areas of poor potential. In the Nottinghamshire area, there are 13 seams that meet the criteria locally, including the High Main, Wales, Top Bright, High Hazles, Top

Hard/Barnsley/Coombe, Dunsil/First Waterloo, Swallow Wood, Deep Soft, Deep Main, Joan/Brown Rake, Parkgate/Tupton, Yard and Blackshale/Ashgate.

There are also large areas where the UCG potential is unverifiable, particularly in the south-east, e.g. between Newark, Sleaford and Lincoln. In this area boreholes are present but do not penetrate down to 1200 m; those examined do not prove coals in excess of 2 m in thickness. Usually only the Lower Coal Measures are present in this area, the lower parts of which are interbedded with igneous rocks (Burgess 1982). Certain seams (e.g. the Parkgate/Tupton/Threequarters and the Dunsil-Waterloo group) are known to combine towards the south and may be thick enough locally to form a resource. Hence UCG resources may be present in this area and warrant further investigation.

North-westwards from Grantham is a mapped area where there are thought to be no UCG resources present (coloured light blue on Map 11). This forms a linear belt that extends for approximately 33 km. In this area the Coal Measures are at depths above 600 m, as they lie along an axis of late Carboniferous uplift (Variscan inversion) along the Eakring structure. Another area where there are no UCG resources occurs in a belt to the north of Boston. Coals are present in this area, although they are deeply buried and only a few occur above 1200 m. Ordinarily such an area would probably contain coals suitable for UCG, however, boreholes in this area (e.g. Apley 1, Beckering 1 and Stixwould 1) prove the base Permian unconformity to be at a depth of approximately 1100 m. The criteria used to determine the presence of a UCG resource discounts all coals within 100 m of the Permian unconformity, hence only coals greater than 1200 m could be considered in this area and these do not qualify as a UCG resource.

34.3 CARBON DIOXIDE SEQUESTRATION

On the eastern side of the map there is a very large area of Coal Measures at depths >1200 m. This may have potential for carbon dioxide sequestration if there is sufficient permeability in the coal seams to allow injection at significant rates.

35 MINING MAP 12a (South Yorkshire)

35.1 REVIEW OF COAL IN THE AREA

The area covered by this map is the northern half of the vast coalfield that lies beneath much of eastern England, east of the Pennines. The part of the outcrop shown on this map runs roughly from Sheffield via Barnsley, to Leeds and Bradford. The Coal Measures dip eastward beneath younger rocks, forming a thick and continuous sheet that reaches the coast between Bridlington in the north and Theddlethorpe in the south. From there it continues eastwards beneath the southern North Sea.

The best coal seams occur in the Lower and Middle Coal Measures. The most valuable and widely extracted seam is the Barnsley coal. Cumulative coal thickness in seams >0.4 m is typically between 14 and 29 m and in the southern half of the area there are commonly several seams >2 m in thickness. In the Selby Coalfield the only seam extracted is the Barnsley coal, which is up to 3 m thick (Figure 30). East of the current mining licences and the North Ouse mining prospect, detailed information on coal seam thickness is not available because there are no continuously cored boreholes. However, information from oil and gas exploration wells suggests that the vast coal resources formerly present in the mined areas, and found in the mining prospects, continue all the way to the coast.

35.2 OPENCAST COAL MINING

As of April 2002 there were 6 working opencast sites in this coalfield (source: DTI web site). Further potential still exists although large urban areas are present on this map, including Leeds, Wakefield and Barnsley.

35.3 UNDERGROUND COAL MINING

The southern part of the vast coalfield shown on this map has been extensively and intensively exploited. Mining has gradually advanced eastwards from the outcrop. Although mining has declined drastically from its peak, the Hatfield and Kellingley mines are still open in the southern area, and the Thorne mine is on care and maintenance. Further north, the Selby Coalfield has been developed from the Ricall/Whitemoor, Stillingfleet and Wistow mines. Only the Top Hard (= Barnsley) coal, which is up to 3 m thick, is extracted in this coalfield. The Selby Coalfield is slated for closure in April 2004.

Further north still is the North Ouse underground mining prospect, previously explored by British Coal.

35.4 COAL MINE METHANE

All the mines in this area drain methane and methane is used in boilers at Ricall/Whitemoor and for power generation at Kellingley (2.8 MWe).

35.5 ABANDONED MINE METHANE

AMM prospects are extremely variable in this coalfield. Along the western flank, in a NNW-SSE trending belt approximately 12 km in width, AMM prospects are thought to be poor. In this area mine workings are largely old and shallow, and mine water is likely to have recovered. In the east, where the workings are more modern and groundwater is being controlled by pumping, prospects for AMM are likely to be good. In the combined Nottinghamshire and Yorkshire coalfields (Maps 11 and 12) this good AMM region covers an approximate area of 666 km^2. Inbetween these two areas the AMM prospects have been mapped as variable and potential may exist but further exploratory work will be required on a site specific basis. In the combined Nottinghamshire and Yorkshire coalfields (Maps 11 and 12) this variable zone covers an approximate area of 1508 km^2. AMM sites are in operation at Monks Bretton, Hickleton and Wheldale collieries, indicating excellent resource potential locally.

36 NEW TECHNOLOGY MAP 12b (South Yorkshire)

36.1 COALBED METHANE

Like those of the Nottinghamshire/Derbyshire/South Yorkshire area, the CBM prospects of this area are poor because of relatively low seam gas contents and uncertainty over the permeability of the coals. This is reflected in the absence of CBM exploration boreholes. The highest average seam gas contents are around Barnsley (5.2 m^3/tonne) with lower values in the North Ouse prospect (3.2 m^3/tonne), the Selby Coalfield (4.7 m^3/tonne) and North Yorkshire (3.6 m^3/tonne).

36.2 UNDERGROUND COAL GASIFICATION

There are large areas in the centre of this map that meet the criteria for UCG. In the west the Coal Measures are too shallow and there are a large number of former and present mine workings and in the east the Coal Measures are too deep (>1200 m). The best area for UCG occurs between Gainsborough and Hatfield. This extends southwards onto Map 11 as far south as Newark and forms an area of 983 km^2 that is suitable for UCG. Other areas with good UCG potential include to the north and south of the Selby mining licence, and north and north east of York. There are 12 seams that meet the >2 m criterion locally (Sharlston Top = High Main, Sharlston Muck, Sharlston Yard, Winter, Kents Thick, Barnsley/Dunsil, Swallow Wood, Lidgett, Flockton Thick, Middleton Little, Middleton Main, Beeston), however, the coals vary considerably in thickness and hence no individual seam meets the thickness cut-off across the entire area. It is considered that the prospects in the unverifiable areas are probably quite good but there is a lack of boreholes >600 m deep.

In most of the map area coals from the Lower and Middle Coal Measures form the thickest seams. North of York erosion at the base Permian unconformity has removed most of the Middle Coal Measures and the UCG potential is restricted to coals from the Lower Coal Measures.

In the east the 1200 m line, drawn on the top of the Coal Measures, marks the eastern limit of UCG resources. However, close to the line only the highest Upper Coal Measures coals actually occur above 1200 m. The thickest coals typically come from the Lower and Middle Coal Measures hence, as the 1200 m line is approached, prospects for UCG diminish because the best coals are too deeply buried. This is marked on the map as a north-south trending fringe of poor UCG resources.

36.3 CARBON DIOXIDE SEQUESTRATION

There is a large area in the east of the map where the coal seams lie at depths greater than 1200 m and therefore may be suitable for CO_2 sequestration.

37 MINING MAP 13a (Ingleton)

37.1 REVIEW OF COAL IN THE AREA

The Ingleton Coalfield forms a small outlier of Coal Measures to the north-west of the town of Ingleton. The exposed coalfield covers an area of approximately 34 km^2. Coals occur in the Lower and probably Middle Coal Measures, with up to 5 coals greater than 0.4 m in thickness and two (Ten Foot and Nine Foot) in excess of 2 m in thickness (Ford 1954). These occur from outcrop down to depths of about 300 m or so.

Currently there are no deep mines in operation in the Ingleton Coalfield with the last mine, New Ingleton Pit, closing in 1940. Records of coal workings are mainly from the south of the coalfield and those coal seams known to have been worked include, in descending order, the Ten Foot, Nine Foot, Four Foot (or Main), Yard, Crow and Six Foot (Figure 31). Optimistically up to 3 m of coal may be present in two seams at about 300 m depth in an area of about 2.6 km^2 in the north of the coalfield but they are unproven. There is no information available regarding coal rank or methane contents of these seams.

The main structure within the area is an east-west trending syncline that plunges to north-east towards the South Craven Fault (Glover et al. 1993). The Coal Measures are cross-cut by a number of NNW-SSE and ENE-WSW trending faults. The Coal Measures are unconformably overlain by younger, reddened Coal Measures and Permian breccias (Ford 1954).

37.2 OPENCAST COAL MINING

There is no opencast potential because the remaining unworked coal seams lie mainly at depths of around 300 m.

37.3 UNDERGROUND COAL MINING

There is no prospect of underground mining as there is only a very small area in the north of the coalfield where two seams of unworked coal may be present and this is not proven.

37.4 COAL MINE METHANE

As there are no working mines there can be no CMM resources.

37.5 ABANDONED MINE METHANE

The Ingleton Coalfield is considered to have very little if any AMM potential because of the low *in-situ* coal reserves. Furthermore mine water levels are expected to be completely recovered.

38 NEW TECHNOLOGY MAP 13b (Ingleton)

38.1 COALBED METHANE

This small coalfield has very poor VCBM prospects because of the coal reserves. There are no published seam gas content measurements.

38.2 UNDERGROUND COAL GASIFICATION

A number of coals (e.g. Ten Feet, Nine Feet and Six Feet seams) meet the thickness criteria for UCG in this coalfield but they have mainly been extracted and do not occur at the depths required to be considered for UCG. Hence there is no UCG resource in this coalfield.

38.3 CARBON DIOXIDE SEQUESTRATION

There is no coal at the depths necessary for CO_2 sequestration and no prospect of CO_2 sequestration in association with UCG or VCBM production.

39 MINING MAP 14a (Cumbria-Canonbie area)

39.1 REVIEW OF COAL IN THE AREA

39.1.1 West Cumbrian Coalfield

Most of the West Cumbrian Coalfield is exposed at the surface. The area of outcropping Coal Measures is approximately 250 km^2 in size. Along the eastern and south-eastern flanks of the coalfield the Coal Measures rest conformably on older Carboniferous (Namurian and Dinantian) rocks. To the south-west there is a small concealed extension below Permo-Triassic strata; this continues to about the St Bees area. The coalfield also continues offshore for at least 14 km. The northern margin of the exposed coalfield is taken at the Maryport Fault, a major ENE-WSW trending normal fault that downthrows to the north-west. However, the coalfield is thought to continue to the north of the Maryport Fault beneath Permo-Triassic cover and it may be connected to the Canonbie Coalfield to the north along the Solway Syncline (Chadwick et al. 1995), although this has not yet been confirmed by drilling.

Currently there are no deep mines in operation in the West Cumbrian Coalfield. Production in the last British Coal mine (Haig) ceased in 1986 and in the last privately owned mine (Mainband Colliery) in c.1993. The coalfield has been extensively worked and more recent mining activities were concentrated in offshore areas.

Coal seams predominantly occur within the Lower and Middle Coal Measures. A few thin seams are known from the lower part of the Upper Coal Measures and the Namurian (Pendleian Stage), but these tend to be of limited significance. The Lower Coal Measures succession tends to be about 130 m in thickness, and the Middle Coal Measures is 200 m thick. Above this there is an unknown thickness of Upper Coal Measures, perhaps 50 to 100 m or so in the exposed coalfield.

In the Lower Coal Measures the thickest seams are the Harrington, Albrighton, Upper Threequarters, Sixquarters and Little Main (Figure 32). The thickest coals occur in the Middle Coal Measures, from the Yard up to the White Metal seams, and these coals can total up to 8 m in a 100 m succession. Coals tend to be thicker in the south and spilt northwards. This is also associated with an increase in the total thickness of the sedimentary succession. Locally around St Bees, the Main, Tenquarters and Bannock-Rattler form about 5 m of coal in a 30 m succession at a depth of about 400 m. Seams are persistent across most of the coalfield but they show a deterioration to the north-east, with only the Yard and, locally, the Tenquarters present (Eastwood et al. 1968).

The main structural trends are a series of NNW-SSE trending normal faults. There is also a subsidiary east-west to ENE-WSW series of normal faults. The coalfield is known to be heavily faulted.

Seams are high volatile, bituminous coals with strong caking properties (Ministry of Fuel and Power 1945). The average methane content of three samples from the Main seam at Haig near Whitehaven is 7.5 m^3/tonne (Creedy 1986). Underground mines in this coalfield were known to be methane rich (Wood 1988).

39.1.2 Canonbie Coalfield

The Canonbie Coalfield is situated at the northern margin of the Solway Syncline. This NNE-SSW trending structure links this coalfield with that of the West Cumbrian Coalfield to the south-west across the Solway Firth (Chadwick et al. 1995). It is likely that the coal seams of Cumbria and Canonbie persist across this structure although this is not proven due to lack of deep boreholes. The north-eastern margin of the coalfield is taken at the east-west trending Rowanburn Fault. The north-western margin is taken at the ENE-WSW trending Gilnockie Fault.

In the Canonbie Coalfield only a limited area (c.18 km^2) of Coal Measures is exposed at or close to the surface, thus limiting the resource area for opencast coal mining. Only limited mining has taken place along the outcrop and considerable potential exists in the concealed coalfield to the south (Picken 1988). Coals are bituminous and have a British Coal Rank of 500-600 and average methane content for coals is 6.3 m^3/tonne (Creedy 1991), with values reaching as high as 7.2 m^3/tonne (Creedy 1983).

The Lower Coal Measures succession is about 120 m in thickness, the Middle Coal Measures is about 230 m and Upper Coal Measures is about 700 m thick. Coals are present in the Lower Coal Measures but are commonly unnamed and are difficult to correlate. Borehole information indicates that they are generally less than 0.8 m in thickness. The main seams are from the Middle Coal Measures, of Duckmantian age, and comprise the Archerbeck, Six Foot, Nine Foot, Three Foot, Five Foot, Black Top and Seven Foot (Figure 33). In the Becklees Borehole coals in this interval total 8.44 m in 94 m of strata compared with 13 m of coal in 99 m of strata in the Rowanburnfoot Borehole. There are only a few thin coals present in the Upper Coal Measures, most of them being located close to the base. The exception is the High Coal, which occurs about 170 m above the base of the Upper Coal Measures.

39.1.3 Midgeholme Coalfield

The term Midgeholme Coalfield is used here *sensu lato* to include all of a series of small ENE trending outliers of Coal Measures marked on Map 14 as the Midgeholme, Plenmeller, Stublick and Hexham coalfields. These coalfields total about 32 km^2 in size. The string of outliers is preserved on the downthrown side of the Stublick Fault. The Westphalian succession is exposed at the surface in all the outliers and dips to the south, towards the Stublick Fault. A generalised stratigraphy is given in Figure 34.

The Midgeholme Coalfield has been worked since the 17^{th} century and was heavily exploited from collieries at Midgeholme, Lambley, Herdley Bank, Featherstone and East Coanwood in the 19^{th} century. An average of 7.6 m of workable coal was present in the Midgeholme outlier. There are 7 seams in the Middle Coal Measures and 4 seams in the Lower Coal Measures. A further seam, the Little Limestone Coal, occurs in the underlying Namurian strata. This occurs in up to 3 leaves, at least two of which commonly come together to form a seam which varies from 0.3 to 1.56 m thick. Judging from outcrop sections it may just be below 600 m depth in the deepest part of the coalfield.

The Plenmellar outlier consists of about 100 m of Lower Coal Measures containing nine seams. Four of these have been worked; the Cannel (0.9 m), the Seven Quarters (1.4 m) the Coom Roof (1.1 m) and the Five Quarters (1.1 m). The Stublick outlier consists of just over 100 m of Lower Coal Measures. Eight seams are present, the best of which is the Main coal (1.1 m).

The coals are mainly of high volatile bituminous rank, but they may be anthracitic adjacent to intrusions. No seam methane measurements are available.

39.2 OPENCAST COAL MINING

39.2.1 West Cumbrian Coalfield

Opencast mining began in this coalfield in 1958 (Wood 1988) and there have been numerous previous opencast mines in this coalfield since then, although there are currently no working sites. There is scope for further opencast activity, particularly in areas away from the coast where there is much rural and moor land available. Numerous thick coal seams occur at shallow depths across this coalfield, although structural complexity is a common feature of opencast sites in this coalfield.

39.2.2 Canonbie Coalfield

The very small size of the coalfield limits the potential for opencast mining.

39.2.3 Midgeholme Coalfield

Shallow coal is present in these coalfields, thus opportunities exist for opencast sites in this area, although the small size of these coalfields limits this potential.

39.3 UNDERGROUND COAL MINING

39.3.1 West Cumbrian Coalfield

This coalfield has had a long history of coal extraction, with coking and steam raising coal mined from the mid-sixteenth century onwards (Wood 1988; Boland & Young 1992). A comprehensive history of coal mining in this coalfield is given by Wood (1988). There is limited potential for further deep mining. The St Bees-Powbeck area in the south-west was explored by drilling in the 1970s, and a number of thick coals were identified at depths of less than 400 m. However, underground mines in this coalfield have always suffered from severe geological problems, particularly faulting, and the high methane content of the seams is known to be a problem.

39.3.2 Canonbie Coalfield

There are currently no underground mining activities in the Canonbie Coalfield. Previous mining activities were of limited extent and ceased during the early part of the 20^{th} century. Geological investigations during the 1950s and 1980s have proved an area of approximately 70 km^2 where coals are present at depths and thicknesses suitable for underground mining (Picken 1988).

39.3.3 Midgeholme Coalfield

Extensive working in the Midgeholme outlier and the small size of the other coalfields precludes further large scale underground working.

39.4 COAL MINE METHANE

As there are no working mines in the coalfields marked on this map there is no CMM potential.

39.5 ABANDONED MINE METHANE

The Wardell Armstrong report for the Coal Authority (2001b) identifies 9 mining blocks in West Cumbria and suggests that mine water recovery is expected to be complete in 7 of these blocks (Cleator Moor, Whitehaven, Oatlands, Workington, Great Clifton, Maryport and Aspatria), with recovery presumed to be complete in the remaining 2 (Welton & Inglewood in the north-east of the coalfield). Hence the prospects for AMM in this coalfield are believed to be poor.

The age of the coal workings in the Canonbie Coalfield would make it likely that mine water levels are fully recovered. This indicates that AMM prospects are poor.

The Midgeholme coalfields are very small and shallow. AMM prospects are therefore thought to be very poor.

40 NEW TECHNOLOGY MAP 14b (Cumbria-Canonbie area)

40.1 COALBED METHANE

40.1.1 West Cumbrian Coalfield

The West Cumbrian Coalfield has relatively high seam methane content. Three samples from the Main seam in the 328s district of Haig colliery had an average methane content of 7.5 m^3/tonne (Creedy 1986). Significant gas flows were obtained from boreholes in the Solway Colliery (Dunmore 1969). However, the onshore parts of the coalfield are present at shallow depths and have been extensively mined, meaning that there are possibly only small isolated pockets of CBM potential. There may be potential in the south, in the St Bees area. However, the high density of faulting may compartmentalise any CBM prospect.

40.1.2 Canonbie Coalfield

The Canonbie Coalfield itself is very small, shallow and essentially exhausted. Its concealed extension (Picken 1988a, b) has an average seam gas content of 6.3 m^3/tonne based on 40 samples from 3 boreholes at an average depth of 876 m (Creedy 1991). However, average seam methane content of one of these boreholes was 7.2 m^3/tonne, with 2.3 m^3/tonne ethane, at an average sample depth of 1143 m (Creedy 1983). It also has the second highest 'gassiness index' amongst the UK coalfields (Creedy 1999) indicating that potentially, flow of gas from boreholes may be above average. It has fair coalbed methane prospects. However, little is known about seam permeability.

40.1.3 Midgeholme Coalfield

The Midgeholme outlier is shallow and has a long history of working. It is unlikely to have VCBM potential. The other two coal-bearing outliers are too shallow to conform to the VCBM criteria.

40.2 UNDERGROUND COAL GASIFICATION

Conditions suitable for UCG are met in parts of the subsurface extension of the Canonbie Coalfield, with the boreholes Becklees and Broadmeadows showing potential. In these boreholes the Nine Foot and an unnamed seam just below the Edmondia Marine Band form the main resource. A further two coals greater than 2 m in thickness occur in the Becklees borehole but at depths greater than 1200 m. Boreholes between these areas indicate that the Nine Foot reduces in thickness (1.74 m in Glenzierfoot, 1.51 m in Staffler and faulted out in Woodhouselees). Hence most of the Canonbie area is thought to have a poor resource potential. To the south, in the Solway Syncline, the potential is unverifiable due to lack of any deep boreholes in this area. Chadwick et al. (1995), using seismic data, suggest that coals are present at suitable depths in the Solway Syncline, overlain by a thick Upper Coal Measures red-bed succession that lacks coals. Hence there may be UCG potential along the eastern and western flanks of the syncline. In West Cumbria, coals are generally present at too shallow depths to form a UCG resource except in the Brayton Domain Colliery 3 borehole on the northern edge of the coalfield, where coals are present at the required depth but do not meet the thickness criteria.

There is no potential in the Midgeholme Coalfield, except possibly in the Little Limestone Coal in the centre of the Midgeholme outlier.

40.3 CARBON DIOXIDE SEQUESTRATION

Coal is likely to occur at depths >1200 m in the Solway Syncline. However, this remains unproven, as there are no boreholes in this area. Therefore any potential is speculative. There is no potential in the Midgeholme Coalfield or the exposed West Cumbrian and Canonbie coalfields.

41 MINING MAP 15a (North East England (south))

41.1 REVIEW OF COAL IN THE AREA

The western boundary of the Northumberland-Durham (North East) Coalfield extends from Amble on the Northumberland coast south-westwards to near Barnard Castle. The Coal Measures in general dip gently to the east and continue beneath the North Sea. A maximum of about 900 m of Coal Measures are present. The major industrial conurbation of Tyne and Wear lies in the centre of the coalfield and the Teeside conurbation lies immediately to the south.

The coalfield has a working history dating back to Roman times. At present however, there is only one working mine remaining, Ellington in Northumberland. Opencast working is very active, with the Butterwell site having been the largest in Britain. The best seams have been exhausted over the entire coalfield and recent working has been mainly offshore beneath the North Sea. A generalised stratigraphy is illustrated in Figure 35.

Workable coal seams up to about 3 m thick and averaging about 0.5 m thick are present in the Lower and Middle Coal Measures, which are up to 725 m thick (Jones 1980). Whilst there are variations in the thickness and quality of almost every seam, the overall thickness of coal is remarkably constant. The total coal thickness between the Brockwell and High Main seams ranges from about 6 to 15.5 m and is generally between 9 and 14 m.

The Lower Coal Measures are about 200 m thick and contain 13 workable seams evenly distributed through the sequence. The best group of seams is in the lowest 150 m or so of the Middle Coal Measures, between the Harvey and High Main Marine Bands. Both the Harvey and High Main coals are over 1.8 m thick in places.

A further 550 m or so of Middle and Upper Coal Measures are present above the High Main Marine Band. This sequence contains numerous thin coals, most of which are too thin to have been worked (<0.3 m), the exceptions being the Usworth and Hebburn Fell coals.

The mean methane content of coals in the Northumberland - Durham Coalfield is 1.3 m^3/tonne (Creedy, 1991). This is based on 82 samples.

41.2 OPENCAST COAL MINING

There is good potential for opencast mining. As of April 2002, there were 7 opencast sites in this area.

41.3 UNDERGROUND COAL MINING

There is little potential for further underground coal mining as there has been very extensive and intensive mining onshore for many centuries, and recent mining has focused on the offshore area.

41.4 COAL MINE METHANE

Coal mine methane is not drained from the Ellington mine and given the low average seam gas content for the coalfield as a whole it appears unlikely that it would form a good CMM prospect.

41.5 ABANDONED MINE METHANE

Much of the North East Coalfield has low initial seam gas contents. Mine water levels have fully recovered in the western fringes of the coalfield. In other parts mine water levels are still recovering or are controlled by pumping. AMM prospects are probably poor over much of the northern and western parts of the coalfield, but limited prospects may be present in the southeast if initial seam gas contents were high enough.

42 NEW TECHNOLOGY MAP 15b (North East England (south))

42.1 COALBED METHANE

The Northeast Coalfield has very low average seam methane contents; average 1.3 m^3/tonne at an average depth of 426 m, based on 82 samples from 18 boreholes (Creedy 1991). However, individual measurements may be somewhat higher (2.8 m^3/tonne in the Low Main seam in Easington, 2.5 m^3/tonne in the Harvey seam in Fishburn Colliery, County Durham). However, these values are not high enough to be of any interest as a VCBM prospect.

42.2 UNDERGROUND COAL GASIFICATION

Conditions suitable for UCG are generally not met or are unverifiable in this area due to the extensive nature of former underground coal workings. Potential only exists in one small area offshore, in the Harvey Seam. However, the full extent of underground mining in this offshore area was not considered as part of this study and there may well be workings in the area regarded as having good potential. Areas with former workings are not considered suitable as a UCG resource.

42.3 CARBON DIOXIDE SEQUESTRATION

The shallow depths to which the Coal Measures are buried and the lack of UCG and CBM prospects means that there is no CO_2 sequestration potential.

43 MINING MAP 16a (North East England (North))

43.1 REVIEW OF COAL IN THE AREA

In this areas coals of Lower Carboniferous, Dinantian age are present, belonging to the Scremerston Coal Member of the Tyne Limestone Formation (Figure 1 & 36). The member is about 305 m thick. There are about 8 - 10 workable seams with an aggregate thickness of 7 m within the member. The best seam is the Scremerston Main Coal, which is about 1.2 m thick on average (Fowler 1926).

43.2 OPENCAST COAL MINING

The presence of shallow coals at outcrop indicates that there is potential for opencast mining in this area.

43.3 UNDERGROUND COAL MINING

There were several pits in the Scremerston area and mining dates back to at least 1764. However, all mines are now closed and potential for further mines is very limited.

43.4 COAL MINE METHANE

There are no working mines in this area and so there is no CMM potential.

43.5 ABANDONED MINE METHANE

There have been only relatively minor underground workings in the Scremerston Coalfield. Some of these are known to be drained by soughs. Others are flooded and there are thought to be no AMM prospects.

44 NEW TECHNOLOGY MAP 16b (North East England (North))

44.1 COALBED METHANE

The coal seams from the Scremerston Coal Member are generally thin and shallow. No seam gas content measurements have been taken and there is generally insufficient information to define the VCBM prospectivity.

44.2 UNDERGROUND COAL GASIFICATION

Coals in this area do not occur in the depth range 600-1200 m. Furthermore, there are no records of coals in excess of 2 m in thickness occurring in this area. Hence it is likely that there is no UCG potential.

44.3 CARBON DIOXIDE SEQUESTRATION

Because there are no realistic CBM or UCG prospects and coals do not occur at depths >1200 m, there is no CO_2 sequestration potential.

45 MINING MAP 17a (Machrihanish)

45.1 REVIEW OF COAL IN THE AREA

The Machrihanish Coalfield covers an area of approximately 27 km^2 on the Mull of Kintyre. Both the Namurian Limestone Coal Formation and the Lower and Middle Coal Measures are present in this coalfield (Figure 37). They form outcrops that trend north-west to south-east, dipping towards the north-east. Upper Coal Measures are also thought to be present but lack coals (Stephenson & Gould 1995).

The Namurian Limestone Coal Formation has been mined in the outcrop area in the SW of the coalfield. Here small faults are common and most of the seams are apparently missing by disconformity towards the east. At least 160 m of Limestone Coal Formation is present. It contains 4 named seams: the Cannel (or Gas), Kilkivan, Main and Underfoot (Figure 37). The Kilkivan and Main have been worked extensively at shallow depths, and the Underfoot has been worked locally. The Main was worked at Argyll Colliery, which closed in 1925, and the Machrihanish Colliery, which closed in 1967. There is a thick sandstone immediately above the Main seam. The Kilkivan Coal occurs some 35 m above the Main Coal.

The Westphalian Coal Measures (Figure 3) have never been worked but up to 460 m of Lower and Middle Coal Measures are believed to be present (Stephenson & Gould 1995). The Vanderbeckei Marine Band has been proved. Coals are uncommon, and vary in thickness and extent, but at least 9 seams are known, with one up to 2 m in thickness. The quantity and quality of coal is controlled mainly by the reddening and oxidation associated with the Permian unconformity.

The northern margin of the coalfield is fault-bounded. Main faults within the coalfield trend NW-SE and ENE-WSW.

There are no seam methane measurements from the coalfield. The coal rank code main class 900, high volatile non-caking, has been recorded for seams worked in the Machrihanish Coalfield.

45.2 OPENCAST COAL MINING

There is no known opencast potential in the Machrihanish Coalfield.

45.3 UNDERGROUND COAL MINING

The small size of the coalfield and previous working indicates that there is no underground mining potential.

45.4 COAL MINE METHANE

There are no working mines and hence no CMM potential.

45.5 ABANDONED MINE METHANE

Mining ceased with the closure of Argyll Colliery in 1927. Mine water recovery is assumed to be complete and therefore there are thought to be no AMM prospects.

46 NEW TECHNOLOGY MAP 17b (Machrihanish)

46.1 COALBED METHANE

The Westphalian Coal Measures are too shallow to be of interest for VCBM, although they contain 4 seams >0.4 m thick. A small area of the Limestone Coal Formation adjacent to the Kilkenzie Fault that defines the northern margin of the coalfield may contain around 5.9 m of coal in 3 seams > 0.4 m thick at depths of approximately 300 - 400 m. VCBM prospects are not known and considered likely to be very poor.

46.2 UNDERGROUND COAL GASIFICATION

In the Machrihanish Coalfield both the Kilkivan and Main coals form seams in excess of 2 m in thickness. Coals dip towards the north-east, so the deepest coals are likely to occur in the extreme north-east of the coalfield. However, there UCG potential is unverifiable due to the lack of any deep boreholes (none are >225 m in depth).

46.3 CARBON DIOXIDE SEQUESTRATION

There is no potential for CO_2 sequestration as there are no coals at depths >1200 m and no realistic UCG or CBM prospects.

47 MINING MAP 18a (West Scotland)

47.1 REVIEW OF COAL IN THE AREA

47.1.1 Ayrshire Coalfield

The Ayrshire Coalfield (which is commonly divided into four parts; North, Central and South Ayrshire and Dailly) covers an area of nearly 1000 km^2. It is situated in a mixed rural and urban area that includes major towns such as Ayr, Irvine and Kilmarnock, and smaller burghs like Cumnock and Dalmellington.

Coal seams are generally confined to the Westphalian Coal Measures Group, although a few coals are known from the lower Namurian Limestone Coal Formation (Figure 38).

The Limestone Coal Formation is generally thin in the Ayrshire Coalfield, ranging in thickness from zero (e.g. in Central Ayrshire) to >200 m (e.g. in North Ayrshire) and is generally less than 50 m in thickness. The total thickness of coal is small, from less than 1.5 m to a maximum locally of 17 m near Cumnock (South Ayrshire). In general, the total thickness of coal is less than 8 m. At Cumnock, there may be up to 13 seams greater than 0.3 m in thickness, with up to 4 over 1 m in thickness. Based on the sequences at Patna and Sorn on the east and west flanks, and on the Cumnock type development of thick coal to the south, a significant amount of coal might be present under at least part of the deeper basin.

The Dailly Coalfield has a relatively thin Limestone Coal Formation succession but with significant quantities of coal, exceptionally >18 m. The strata tend to be quite steeply dipping. The Westphalian Coal Measures are absent in the Dailly Coalfield.

The Lower Coal Measures are rather poorly known but are up to 236 m thick with 10.2 m of coal in 12 seams from 0.4 to 2.2 m thick; coals form 2-4% of the succession. The Middle Coal Measures are between 154 m and 174 m thick and between 3 and 7 seams exceed 0.4 m, up to a maximum of 2.23 m thick. The Upper Coal Measures are commonly devoid of coals due to Permian oxidation, although locally there may be as many as 8 seams present between 0.4 m and 1.12 m in thickness.

The coal rank codes fall in the main classes 700-800, high volatile caking to non-caking. Locally coking coal occurs where basic igneous intrusions have thermally metamorphosed the coals. The methane content of the Ayr Hard and Main seams in the Coal Measures at Killoch Colliery were 2.8 and 2.0 m^3/tonne respectively (Creedy 1985).

47.1.2 Douglas Coalfield

The small Douglas Coalfield is located in a low-lying, predominantly rural area. Mining in the coalfield ceased some years ago. Although mining of the shallower seams has been extensive, the deeper reserves in the centre of the coalfield are largely untouched.

Geologically, the coalfield lies in a small, deep, NE/SW elongated synclinal basin. The Carboniferous succession thins rapidly in all directions from the basin centre. To the northwest and southeast the thinning is controlled by major NE-trending faults; the Carmacoup and Kennox Faults respectively.

These two structures appear to have exercised control on sedimentation from late Dinantian times onwards. They effectively form the northern and southern margins of a relatively small prospective area where coal seams are buried to depths of 800 m to more than 1200 m.

The axis of the major fold in the Douglas Coalfield trends northeast with dips on its flanks ranging from <10° to >60°. Faulting observed both in the exhausted Coal Measures mine workings and deep drilling by British Coal is significant and may be closely spaced. Closely spaced faulting is likely to adversely affect ECBM projects and UCG prospects.

Potentially useful seams occur within the Westphalian Coal Measures, and the Passage, Upper Limestone and Limestone Coal formations (Figure 38). The more important intervals are parts of the Lower and Middle Coal Measures and the Limestone Coal Formation. Because of the steep dips, the thickness of coal seams quoted below may be somewhat exaggerated as many borehole records do not correct for this dip.

In the Westphalian, the Upper Coal Measures are about 340 m thick and contain a few thin coals, of which one in the upper part is over 1 m thick. The Middle Coal Measures are about 315 m thick and contain around 19 m of coal. Records show >9 to 16 seams over 0.3 m thick and 5-6 seams over 1.3 m. The Lower Coal Measures are about 345 m thick and contain around 20 m of coal. Records show >9-17 seams over 0.3 m thick and >3-9 seams over 1.3 m.

In the Namurian, the Passage and Upper Limestone Formations are rather variable in development, with the former markedly affected by internal unconformities. They are usually thin except in the middle of the syncline. They contain locally developed seams including the Manson Coal in the Passage Formation that varies from 0 – 4 m and is exceptionally 15 m thick (uncorrected for 55^{o} dip). Within the Upper Limestone Formation, there are 6 seams of some interest (1 - 4m thick) including the Gill, Orchard and Ellenora in the interval between the Calmy Limestone and the Index Limestone. In total, 4-17 m of coal is found within 103-230 m of sequence.

The Limestone Coal Formation varies in thickness from less than 70 m to 254 m in the axis of the basin. The higher value is uncorrected for dip of 30^{o}-60^{o}. In the upper part of the formation (above the Black Metals Marine Band), 3-19 m of coal is present in 35-125 m of succession. There are 4-11 seams over 0.3 m thick and 1-6 of these are more than 1.0 m thick. In the generally less coaly lower part, 1.5-10 m of coal is present in 62-125 m of strata. Up to 5 seams are over 0.3 m and 2 over 1 m thick.

Most of the coals in this area fall into the British Coal's Coal Rank Code main classes 700 and 800. They are high volatile caking to non-caking bituminous coals. Their methane content is not known.

47.1.3 Sanquhar Coalfield

Isolated in the Southern Uplands, south of the Midland Valley, the NW-SE elongated Sanquhar Coalfield contains Westphalian Lower and Middle Coal Measures, about 300 m thick. These strata are overlain by about 360 m of Upper Coal Measures. The Coal Measures are underlain by a very thin succession (50-80 m) of Namurian and Dinantian sedimentary rocks totally devoid of coal. The Limestone Coal Formation is not present, restricting prospectivity to the Coal Measures.

The position of the coalfield is controlled by a major NW-trending fault on its north-east side. The main structure within the coalfield is a NNE trending faulted syncline. Some of the coal seams in the Coal Measures of Sanquhar have been extensively worked especially those in the Middle Coal Measures. The coal rank code main classes recognised are 600-800, high volatile caking to non-caking. No methane data has been published.

47.2 OPENCAST COAL MINING

47.2.1 Ayrshire Coalfield

Significant areas technically amenable to opencast coal mining occur in the Ayrshire Coalfield. The main prospects are the Lower and Middle Coal Measures and also the Limestone Coal Formation (with some seams in the overlying Upper Limestone Formation). Quaternary deposits are usually less than 40 m thick and do not generally restrict the areas available to opencasting. The coal seams are generally low sulphur but certain seams reach 8-12 % sulphur. East Ayrshire is currently the hub of opencast mining. Among the 12 active sites are House of Water, Powharnal, Spireslack and Burnfoot Moor Open Cast Coal Site (OCCS). The first two are currently working in Coal Measures and the second two in the Limestone Coal Formation.

47.2.2 Douglas Coalfield

Significant areas technically amenable to opencast coal mining occur in this small coalfield. The main targets are the Lower and Middle Coal Measures and the Limestone Coal Formation. A few coals in the Upper Limestone Formation have augmented the available reserve in sites working the Limestone Coal Formation. However, it must be underlined that as a key area in the current supply of opencast coal in Scotland the number of major sites still to be found is diminishing. Largely unconsolidated Quaternary deposits cover the Carboniferous rocks to depths usually around 6-20 m but locally over 40 m. They do not generally restrict the areas available to opencasting. The coal seams are generally low sulphur. Among the active opencast sites in this area are Glentaggart OCCS that works Coal Measures and Broken Cross OCCS in the Limestone Coal Formation.

47.2.3 Sanquhar Coalfield

There is minor potential for opencast coal production in this coalfield.

47.3 UNDERGROUND COAL MINING

47.3.1 Ayrshire Coalfield

Killoch, Barony and Highhouse collieries in East Ayrshire were the last active deep mines to close in the early 1980s. These worked Coal Measures strata. The worked seams were troubled by both igneous intrusions with metamorphism of the coal and by transformation of coal to limestone in response to oxidation related to the base Permian unconformity. The Middle Coal Measures were the focus of the more recent mining but few seams exceed 2 m thick (Tourha and Ayr Hard). In the Lower Coal Measures the Knockshinnoch Main exceeds 2 m but other seams are usually less than 1.5 m thick. However, it is possible that there are extensive remaining reserves under the Mauchline area.

There are still extensive areas of deep coal in the Limestone Coal Formation, possibly limited by the local development of seams over 1.5 m thick in a generally thin succession. However, the Common No 1/80 Borehole (NS52SE) reached this formation at a depth of 563 m. The unit was 97 m thick with four coals thicker than 0.4 m, but dolerite intrusions ruined the thickest two seams namely the Main Gasswater (5.44 m) and the Lower Gasswater (2.92 m). The other two seams were 0.9 m and 1.59 m (McDonald) thick.

47.3.2 Douglas Coalfield

The last deep mines closed in this part of central Scotland at least two decades ago. The Coal Measures are essentially exhausted at shallow to moderate depths but reserves of coal exist at depth and in the underlying Limestone Coal and Lower Limestone formations. The Gallow Knowe, Eggerton, Bloodmyre and other boreholes drilled in the late 1970s were designed to explore the continuing deep mine potential of this coalfield. Complex faulting, folding, seam thickness variation and steep dip make this prospect less attractive.

47.3.3 Sanquhar Coalfield

There is no potential for underground mining in the Sanquhar Coalfield.

47.4 COAL MINE METHANE

There are no working mines and therefore no CMM prospects in any of the coalfields on this map.

47.5 ABANDONED MINE METHANE

47.5.1 Ayrshire Coalfield

It would be expected that water levels have recovered over most of North Ayrshire. Mining ceased in the late 1960s. Gravitational water outflows occur in the west of the area. Thus there are probably only very limited AMM prospects, even if initial seam gas contents were high enough for AMM production.

Mining in Central Ayrshire ceased in 1989 with the closure of Barony Colliery. It is likely that mine water is fully recovered in most of central Ayrshire, except possibly around Ochiltree and Auchinleck. Thus there may be limited AMM prospects in this area if initial seam gas contents were high enough for AMM production.

In south Ayrshire, surface outflows of mine water indicate that mine waters have generally recovered. Thus there are probably only very limited, if any, AMM prospects even if initial seam gas contents were high enough for AMM production.

47.5.2 Douglas Coalfield

It is likely that in general the mine water levels in the Douglas Coalfield are recovered. The last mine closed at least two decades ago. Thus AMM prospects are probably poor, even if initial seam gas contents in the mines were high enough for AMM production.

47.5.3 Sanquhar Coalfield

Mine water levels in this coalfield are still recovering. Thus there may be very limited AMM prospects if initial seam gas contents were high enough.

48 NEW TECHNOLOGY MAP 18b (West Scotland)

48.1 COALBED METHANE

48.1.1 Ayrshire Coalfield

The Westphalian Coal Measures are heavily worked, except beneath the centre of the Mauchline Basin in Central Ayrshire. Measured seam gas contents are low (2.8 and 2.0 m^3/tonne in the Ayr Hard and Main seams respectively at Killoch Colliery). VCBM prospects in these strata are considered to be poor.

The total thickness of coal in the Limestone Coal Formation is generally low, ranging from less than 1.5 m in 50 m to a maximum locally of 17 m in 127 m of strata near Cumnock (South Ayrshire). The strata are steeply dipping and the true thickness may be rather less. From 0-13 seams may be over 0.3 m thick, with 0-4 over 1 m thick. In the Ayrshire Coalfield in general, the total thickness of coal in the Limestone Coal Formation is commonly (much) less than 8 m.

The Dailly Coalfield is a relatively small and shallow structure. The Westphalian Coal Measures are absent. It has a relatively thin Limestone Coal Formation succession with significant quantities of coal; exceptionally >18 m in 45 m. Because it is shallow, seam gas contents may be relatively low and the VCBM prospectivity may thus be lower than in the deeper parts of the main Ayrshire Coalfield.

The gas content of the Limestone Coal Formation coals is not known in any of the Ayrshire coalfields.

Given that there are only 4 seams >1 m thick in the Limestone Coal Formation in the best part of the Ayrshire Coalfield, and in general the total thickness of coal is much less than 8 m, it is unlikely to be an early target for CBM exploration. The Ayrshire Coalfield is intensively faulted, further downgrading its prospectivity.

48.1.2 Douglas Coalfield

The Douglas Coalfield contains significant thicknesses of coal in the Westphalian Coal Measures, the Limestone Coal Formation and intervening strata, especially in the deep central part of the coalfield, between the Carmacoup and Kennox faults. This makes it potentially an interesting area for VCBM exploration.

There are no measurements of seam gas content available for this coalfield. By analogy with published measurements from the other Scottish coalfields (Creedy 1991), it is assumed that the seams above the Limestone Coal Formation will have low seam gas contents insufficient to establish VCBM production. The potential of the Limestone Coal Formation is not known.

48.1.3 Sanquhar Coalfield

In its deepest part, the Sanquhar Coalfield consists of Westphalian Lower and Middle Coal Measures about 165 and 300 m thick respectively, overlain by about 360 m of Upper Coal Measures. It contains about 7 m of coal in 9 seams. Of these, three (the Creepie, the Calmstone and the Kirkconnel Splint) are persistently thick. The coals are of high volatile rank and no seam methane content measurements have been published. However, by analogy with other Scottish coalfields, and bearing in mind their relatively shallow depth over much of the coalfield, seam methane values are considered likely to be very low. VCBM prospects are thus considered to be very poor.

48.2 UNDERGROUND COAL GASIFICATION

48.2.1 Ayrshire Coalfield

Conditions suitable for UCG are generally limited in this area due to the extensive nature of previous underground mining activity. However, areas with good potential for UCG have been identified. The largest area in the Ayrshire Coalfield is between Mauchline and Ochiltree. Seams proved to exceed 2 m thick at the correct depths in areas not associated with old mine workings are restricted to two boreholes: Kingencleuch No 1 (Hurlford Main 2.52 m at 937 m) and Drumfork Farm Bore (Lugar Main 2 m at 717 m). These two coals are from the Middle Coal Measures. A large area of unverifiable UCG potential exists to the west of the area of good potential. Boreholes are present in this area but typically do not penetrate to depths much in excess of 600 m and no thick coals have been recorded. Hence this is an area that may have potential.

48.2.2 Douglas Coalfield

In the Douglas Coalfield only the Callow Knowe, Douglas Bh.76 Diamond and Eggerton boreholes proved coals suitable for UCG. In the latter borehole the Manson Coal in the Passage Formation was about 8.12 m thick, corrected to 4.66 m for a dip of 55^{o} at a depth of only 260 m. However, this is in a mined area so has been discounted. In the Callow Knowe Borehole this seam was 2 m thick at a depth of 871 m. In the Douglas Bh.76 Diamond the Ponfeigh Gas (2.41 m, at 623 m), from the Upper Limestone Formation, and the Wee Drum (5.54 m at 781 m) and the Skaterigg coals (3.28 m at 792 m) from the Limestone Coal Formation are all considered suitable for UCG.

48.2.3 Sanquhar Coalfield

There is no potential for UCG in the Sanquhar Coalfield.

48.3 CARBON DIOXIDE SEQUESTRATION

48.3.1 Ayrshire and Douglas Coalfields

There are only small areas on this map where coal-bearing strata occur at depths greater than 1200 m and hence would be suitable for carbon dioxide (CO_2) sequestration. These occur in the Douglas Coalfield and also in the Ayrshire Coalfield between Tarbolton and Ochiltree. In addition to this CO_2 sequestration may also be feasible across all areas where CBM and UCG can take place. The best location for such a scheme would occur where there are good prospects for UCG and a correspondingly high methane content. Such a situation occurs in area in the Ayrshire Coalfield between Mauchline and Ochiltree.

48.3.2 Sanquhar Coalfield

There is no potential for CO_2 sequestration in the Sanquhar Coalfield.

49 MINING MAP 19a (East and Central Scotland)

49.1 REVIEW OF COAL IN THE AREA

49.1.1 Central Coalfield

The Central Coalfield covers an area of 1100 km^2. The (Westphalian) Coal Measures coalfield centred on Glasgow, Airdrie, Carluke and East Kilbride is essentially exhausted after intensive mining since the industrial revolution. The main resources are in the Limestone Coal Formation but they are limited by the general lack of seams over 1.5 m thick. A generalised stratigraphy for this area is shown in Figure 38.

Currently there are no deep mines in operation in this area. Cardowan Colliery, in the western part of the coalfield, was the last deep mine to close. Cardowan Colliery was noted as a particularly gassy pit. Indeed methane was systematically collected and sold commercially to a local whisky plant. Gassy pits extended eastwards to Herbertshire near Falkirk. The Chryston area of north-east Glasgow is blighted by the escape of methane gas from the Carboniferous bedrock to the surface.

49.1.2 Clackmannan and North East Stirlingshire Coalfields

The Clackmannan and North East Stirlingshire coalfields cover an area of 540 km^2 and are centred on the towns of Alloa and Falkirk, north and south of the Forth respectively.

There has been widespread exploitation of coal resources in this area within the largely exhausted productive Coal Measures, the Upper Limestone Formation and the Limestone Coal Formation. A generalised stratigraphy for this area is shown in Figure 38. The Longannet Mine Complex, the last deep mine in Scotland, was forced to close by flooding in 2002. The Coal Measures are essentially exhausted. However, in the overlying Upper Limestone Formation, the Plean No1 Coal is up to 2 m thick and the Upper Hirst seam up to 3.7 m thick. Both seams are known to diminish substantially in thickness on a regional basis. The Upper Hirst Coal was extensively mined at the Longannet Mine complex. However, there are still considerable areas within which both seams are intact and more than 500-800 m below ground.

There are still extensive areas of deep coal in the Limestone Coal Formation, although their resource potential is limited by the general lack of thick seams. However, over 25 seams may be more than 0.3 m thick in the best areas, producing a total cumulative thickness of 8 to 24 m of coal. However, the number of seams diminishes both to the west and south to 6 or less. The seams that reach 3 m thick such as the Bannockburn Main Coal complex (Stirling) and the west Fife Jersey complex (=Wester Main of Bo’ness) are rather variable and are characterised by common seam splitting.

Many of the coals in this area fall into the British Coal's Coal Rank Code main classes 500, 600, 700, 800 and 900. These are high volatile very strongly caking to non-caking bituminous coals. There is a distinct increase in coal rank from east to west across the coalfield such that small quantities of class 100 (anthracite) and 300 (coking) coals were once mined in the Stirling area.

The Airth coalbed methane project, near Kincardine Bridge, is in the coalfield. This has produced flows of coalbed methane and water from the Limestone Coal Formation (Bacon 1995).

Geologically, the coalfield comprises is a synclinal fold, known as the Clackmannan Syncline. Its axis trends broadly north-south and the inclination of the strata on its flanks is between 3-14 degrees. In general, faulting is neither severe nor closely-spaced. The general trend of the faulting is east-west, the main faults being the Ochil, Abbey Craig, Alloa, Clackmannan, and Kincardine Ferry faults. They all throw down to the south, the maximum values being in the range of 120-240 m, with the exception of the West Ochil Fault. This forms the northern margin of the coalfield and is a more fundamental structure with a throw of as much as 1300 m. Other important faults trend NW-SE, e.g. the Sheardale and Arndean faults. These have large downthrows to the south-west.

49.1.3 Fife Coalfield

The Fife Coalfield covers an area of approximately 450 km^2. The towns of Dunfermline, Glenrothes and Kirkcaldy lie in the area with smaller burghs like Leven on the coast. A generalised stratigraphy for this area is shown in Figure 38.

There has been widespread exploration for coal resources in this area principally within the largely exhausted Coal Measures. A little deep mining has taken place in the Limestone Coal Formation on- and offshore at the former Rothes and Seafield collieries. Rothes closed because of a variety of problems including water, thin coals, burning of seams by a major quartz-dolerite intrusive sill and volcanic necks affecting seam quality. At Seafield, steep dips limited the interest in the Limestone Coal Formation as thicker and often less steeply dipping seams were available in the Coal Measures.

To the south the Fife Coalfield forms part of a major fold structure, the Leven Syncline, which continues southwards beneath the Firth of Forth and emerges on the south side of the Firth as the Lothian Coalfield. Much of the deeper prospects lie beneath the Leven Syncline and the smaller Thornton-Balgonie and Lundin Coalfield synclines to the west and east respectively. The Carboniferous succession in the Leven Basin thins westwards and eastwards over the Burntisland Anticline and the Earlsferry Anticline. These structures appear to have exercised control on sedimentation from late Dinantian times onwards.

The axes of the folds trend broadly north-south and the inclination of the strata usually is between 10-18 degrees. In general, faulting as observed in the exhausted Coal Measures mine workings is neither severe nor closely spaced. However, the Limestone Coal Formation is more affected by folding and faulting.

Most of the coals in this area fall into the British Coal's Coal Rank Code main classes 700, 800 and 900. These are high volatile caking to non-caking bituminous coals.

The Carboniferous sedimentary rocks have been intruded by igneous sills of quartz- and olivine (teschenitic)-dolerite, commonly 60-160 m thick. The occurrence of agglomerate-filled vents and pipes of basaltic intrusions also show that igneous activity will have a locally important influence on coal rank and the presence or loss of methane.

49.1.4 Lothian Coalfield

The Lothian Coalfield covers an area of about 270 km^2. The city of Edinburgh lies immediately west of the Lothian Coalfield. The area is generally low-lying, with the Pentland Hills to the west and the Lammermuir Hills to the east. Away from the coast and south of Edinburgh much of the coalfield is rural. A generalised stratigraphy for this area is shown in Figure 38.

The Westphalian Coal Measures have been very heavily worked and are essentially exhausted. Deep mining ended with the closure of Monktonhall Colliery in 1994. Most of the remaining resources lie the Limestone Coal Formation.

The thickest and deepest part of the coalfield lies beneath the Midlothian Syncline. This plunges to the north such that the Limestone Coal Formation seams are buried to depths of 800 m under the coastal strip at Musselburgh.

The Midlothian Syncline continues northwards beneath the Firth of Forth and emerges on the north side in the Fife Coalfield. Offshore it is referred to as the Leven Syncline. In general, faulting observed in the exhausted Coal Measures mine workings is not severe but may be closely spaced.

The Carboniferous sedimentary rocks have been intruded by igneous dykes of quartz-dolerite but these are known mainly in the offshore area. They will have had little influence on seam rank (i.e. coking, anthracitising or decarbonising) or chemistry. Only detailed investigation would reveal the effect of the intrusions on methane occurrence, production and loss.

In the Lothian Coalfield as a whole, up to 15 seams in the Limestone Coal Formation exceed 1 m in thickness. The total cumulative thickness of coal between the Index Limestone and North Coal is 3-28 m. Most of the coals are high volatile caking to non-caking bituminous coals.

The mean methane content of the Stairhead Seam in the Limestone Coal Formation is 0.8 m^3/tonne (Creedy 1981). If this measurement is representative of the virgin gas content in the Limestone Coal Formation, it is far too low for the coalfield to be considered as a coalbed methane prospect and ECBM would not be viable.

In parts of the area, there is some possibility of supplementing the potential resource base in the Limestone Coal Formation. Additional coal seams about 1 m thick occur in the overlying Upper Limestone and underlying Lower Limestone formations.

49.2 OPENCAST COAL MINING

49.2.1 Central Coalfield

Significant areas technically amenable to opencast coal mining occur in this area. The main targets are the Middle and Lower Coal Measures and to a lesser extent the Limestone Coal Formation. Apart from parts of the Kelvin and Clyde valleys, largely unconsolidated Quaternary deposits cover the Carboniferous rocks to depths usually around 6-20 m but locally over 40-90 m in the above valleys' bedrock depressions. They do not generally restrict the areas available to opencasting. The coal seams are generally low sulphur. The Damside OCCS, Drumshangie OCCS and Watsonhead OCCS in North Lanarkshire are three of the currently active sites in the Coal Measures.

49.2.2 Clackmannan Coalfield

Significant areas technically amenable to opencast coal mining occur in this area. Main prospects are the Lower and Middle Coal Measures and the Limestone Coal Formation. Thick Quaternary deposits (50 to>90 m) in the Carron, Forth and Devon valleys restrict the areas available to opencasting. The coal seams are generally low sulphur. Meadowhill OCCS in Clackmannanshire is currently active, extracting coals from the Lower Coal Measures.

49.2.3 Fife Coalfield

Significant areas technically amenable to opencast coal mining occur in the Fife Coalfield. The main coals occur in the Lower and Middle Coal Measures and the Limestone Coal Formation. Exceptionally, as thick coal is not normally a feature of this unit, there are reserves remaining in the Passage Formation in the Lochore Basin at Westfield OCCS. Apart from the coast, where bedrock is seen on parts of the shore, largely unconsolidated Quaternary deposits cover the Carboniferous rocks to depths usually around 6-10 m but locally over 30 m. They do not generally restrict the areas available to opencasting. Although offshore, the SeaLab No 2 Borehole provides a reference for the amount of coal present the Lower and Middle Coal Measures. The relevant part of the Middle Coal Measures contains 6-8 seams thicker than 0.4 m amounting to a cumulative thickness of about 10.3 m of coal (5%) in 198 m of strata. The Lower Coal Measures contain a similar number of coals but up to 3.3 m thick, with a cumulative coal thickness of 11.68 m of coal (4%) in 289 m of strata. The coal seams are generally low sulphur. Randolph OCCS and Woodbank Remediation OCCS are currently active in Lower Coal Measures. The Begg Farm OCCS, Colton Extension OCCS and Greenbank Extension OCCS are currently extracting the Limestone Coal Formation.

49.2.4 Lothian Coalfield

Significant areas technically amenable to opencast coal mining occur in the Lothian Coalfield. The main prospects are the Lower and Middle Coal Measures and the Limestone Coal Formation. Exceptionally, there are potential reserves in the Passage Formation, e.g. the Eskmouth Extra Coal in the Musselburgh area but these are largely in built-up areas. Apart from parts of the North and South Esk valleys, largely unconsolidated Quaternary deposits cover the Carboniferous rocks to depths usually around 6-20 m but locally over 40 m. However they do not generally restrict the areas available to opencasting. The coal seams are generally low sulphur. The Mentieth Houses OCCS and Oxenfoord West OCCS are currently active sites in the Limestone Coal Formation.

49.3 UNDERGROUND COAL MINING

49.3.1 Central and Clackmannan Coalfields

There has been intensive and extensive coal mining in this area since the industrial revolution. However, the closure of Longannet Mine in 2002 ended deep mining in the area. There are still extensive reserves, e.g. in the Hirst coal and the Limestone Coal Formation but those in the Limestone Coal formation are limited by the general lack of seams over 1.5 m thick.

49.3.2 Fife Coalfield

Seafield and Frances collieries were the last of the deep mines to close in Fife, in the 1980s. The Coal Measures are essentially exhausted onshore but extensive reserves of coal exist under the Firth of Forth in the former take of the Michael, Frances and Seafield collieries. In the Michael Colliery, the Lower Coal Measures contain about 18 m of coal in 9 seams over 0.4 m thick. To this total in the general area including Frances and Randolph collieries can be added from 1 m to 3 m for the Lethemwell Coal in the top of the Passage Formation. The key seams are the Barncraig, Coxtool, Chemiss, Bowhouse, Branxton, Dysart Main, Coronation and Lower Dysart. All but the Branxton are normally 2 m thick or more. There are still extensive areas of deep coal in the Limestone Coal Formation but their resource potential is limited by the general lack of seams over 1.5 m thick. The clearest but largely unproven prospect lies to the east of the former Rothes Colliery and extends across the coastal plain under the Firth of Forth. The Windygates, Cameron Bridge and Wellsgreen boreholes give some indication of the potential. In these there are between 16 and 21 seams thicker than 0.4 m, of which 3 to 7 are thicker than 1 m and 0 to 2 more than 2 m. The seams exceeding two metres are the Little Splint, Cowdenbeath Five Foot and Largoward Thick but they do not necessarily exceed 2 m in the same boreholes. In the Windygates Borehole there are 22 m (6%) of coal in 341 m of strata.

49.3.3 Lothian Coalfield

Monktonhall Colliery was the last of the deep mines to close in this part of central Scotland and was working coals in the Limestone Coal and Lower Limestone formations. The Coal Measures are essentially exhausted and the resource potential of the reserves of coal that exist in the Limestone Coal and Lower Limestone formations are limited by the general lack of seams over 1.5 m thick. Under Musselburgh and offshore under the Firth of Forth all the coal-bearing formations have good potential. The most recent drilling focussed on the Coal Measures (Briarthorn Nos 1-6 boreholes). Thick coals near the base of the Lower Coal Measures and top of the Passage Formation are of particular interest.

49.4 COAL MINE METHANE

As there are no working mines in the area covered by the map, no coal mine methane is now produced.

49.5 ABANDONED MINE METHANE

49.5.1 Central Coalfield

A general assessment of mine water recovery in this area is difficult. There are few mine water outflows in the western part of the coalfield and those in the east are pumped from Polkemmet Colliery. There may be AMM prospects in limited areas if initial seam gas contents were high enough.

49.5.2 Clackmannan Coalfield

It is probable that mine water levels have recovered in this coalfield. The last mine, Longannet, was closed due to flooding in 2002. Methane levels in the Westphalian Coal Measures are likely to be low in most mines, whereas in the Limestone Coal Formation they may be significant. However, AMM prospects are poor because of the likely mine water recovery.

49.5.3 Fife Coalfield

Mine waters in the Limestone Coal Formation in this coalfield have recovered and a number of surface water discharges exist. The Westphalian Coal Measures workings are interconnected - apart from those at Seafield Colliery. They are believed to be recovering as a single unit. However initial seam gas contents in the Westphalian Coal Measures are probably too low for AMM production. The mean methane content of the Bowhouse and Dysart Main seams in the Lower Coal Measures is 0.6-1.2 m^3/tonne (Creedy 1991).

49.5.4 Lothian Coalfield

Mine waters in the relatively shallow East Lothian Coalfield and shallow workings in the Midlothian Coalfield are probably recovered. Mine waters in the deep Midlothian Coalfield are probably recovering. In the western part of the Midlothian Coalfield, mine waters are pumped from the former Moncktonhall Colliery.

50 NEW TECHNOLOGY MAP 19b (East and Central Scotland)

50.1 COALBED METHANE

50.1.1 Central Coalfield

The Central Coalfield has been heavily worked since the industrial revolution. The Westphalian Coal Measures are largely exhausted and probably contain few viable VCBM prospects.

The total thickness of coal in the Limestone Coal Formation in seams >0.4 m thick varies between approximately 1.8 and 12 m, with the highest values confined to the Kilsyth Trough and the southern extension of the Clackmannan Basin beneath the Falkirk-Stane Syncline. Further seams are present in Dinantian strata beneath the Limestone Coal Formation. Seam gas content measurements (Creedy 1986) are given in Table 8.

Cardowan Colliery, in the east of the area, adjacent to the Clackmannan Syncline, was known to be a gassy colliery. VCBM prospects in the Limestone Coal Formation probably increase to the east towards the Clackmannan Syncline.

50.1.2 Clackmannan Coalfield

The Clackmannan Coalfield may be the most prospective of the Scottish Midland Valley coalfields. Seam methane contents are 8-10 m^3/tonne in the Limestone Coal Formation at Airth. Significant gas and water production has been established from VCBM wells in the Limestone Coal Formation (Bacon 1995). There are ten seams in the Limestone Coal Formation at Airth. Permeability measured after hydrofracturing of the seams is reported as up to 25 mD (Creedy 1999). Nonetheless, economic gas production has not been established.

50.1.3 Fife Coalfield

The mean methane content of the Bowhouse and Dysart Main seams in the Lower Coal Measures is 0.6-1.2 m^3/tonne (Creedy 1981). This demonstrates that the Westphalian Coal Measures have no potential as a coalbed methane prospect. There has been no CBM exploration to date in the Fife Coalfield.

Between 2 and 8 seams in the Limestone Coal Formation are >1 m thick. No seam gas content measurements have been made in the Limestone Coal Formation coals. The seams are at their deepest beneath the coast of the Firth of Forth and offshore between the Fife and Lothian coalfields. The VCBM prospectivity is uncertain.

50.1.4 Lothian Coalfield

The mean methane content of the Stairhead Seam in the Limestone Coal Formation is 0.8 m^3/tonne (Creedy 1981). If this measurement is representative of the virgin gas content in the Limestone Coal Formation, it is far too low for the coalfield to be considered as a VCBM prospect. There has been no CBM exploration to date in the Lothian Coalfield.

50.2 UNDERGROUND COAL GASIFICATION

50.2.1 Central and Clackmannan Coalfields

There are three areas considered suitable for UCG in the Clackmannan and Central coalfields. These are to the north-west of Falkirk, and two areas along the Firth of Forth. Coals that meet the criteria are the Upper Hirst (Upper Limestone Formation), Bannockburn, Wester Main, Kelty Main and No.1 and 2 Jersey coals, Glassee and Mynheer from the Limestone Coal Formation. Good prospects occur northwards from Grangemouth to the area of the former Longannet Colliery and north and west of Stenhousemuir. It is possible that the good areas extend further to the south-west, into the area between Falkirk and Cumbernauld. However, there are few deep boreholes hence this area is marked as unverifiable.

50.2.2 Fife Coalfield

In Fife there are two small areas that meet the criteria for UCG, one onshore and one offshore. The onshore area occurs between Glenrothes and Methil, whereas the offshore area lies along the western flank of the Leven Syncline. Coals meeting the criteria include the Upper Limestone Formation Craig Coal, and the Upper Cardenden Smithy, Lochgelly Splint, Cowdenbeath Jewel and Cowdenbeath Five Foot from the Limestone Coal Formation. To the north and east of this good UCG prospect is a large area of unverifiable UCG. Here there are no boreholes greater than 600 m in depth.

50.2.3 Lothian Coalfield

In Lothian the coal-bearing strata are limited to a narrow synclinal area between Musselburgh and Penicuik. The extensive former underground coal mining restricts the areas available for UCG exploitation. However, small areas with potential exist immediately offshore from Musselburgh and to the south-east of Edinburgh. Seams that meet the criteria include the Lower Coal Measures

Musselburgh Fifteen Foot and Seven Foot and, from the Limestone Coal Formation, the Great, Gillespie and Blackchapel.

50.3 CARBON DIOXIDE SEQUESTRATION

50.3.1 Clackmannan Coalfield

There is a small area where the Limestone Coal Formation is at depths >1200 m in the extreme north of the Clackmannan Syncline. This may have theoretical potential for CO_2 sequestration in unminable coal. There is a possibility that CO_2 sequestration could take place as part of an ECBM project if commercial CBM production can be established. There are areas of good UCG potential in the Central and Clackmannan coalfields where there may be potential to combine UCG and CO_2 sequestration.

50.3.2 Fife Coalfield

There is a small area where the Limestone Coal Formation is at depths >1200 m near the Fife coast. This may have theoretical potential for CO_2 sequestration in unminable coal. There are small areas of good UCG potential in the Fife Coalfield (onshore and offshore) where there may be potential to combine UCG and CO_2 sequestration.

50.3.3 Lothian Coalfield

There are two small areas of good UCG potential in the Lothian Coalfield (one offshore and one onshore) where there may be potential to combine UCG and CO_2 sequestration.

50.3.4 Leven Syncline

The only areas where the Westphalian Coal Measures reach depths >1200 m and therefore have potential for CO_2 sequestration in unminable coals, is in the centre of the Leven Syncline beneath the Firth of Forth. Further potential may exist in the Limestone Coal Formation in the Leven Syncline.

51 MINING MAP 20a (Brora)

51.1 REVIEW OF COAL IN THE AREA

The Brora Coalfield forms a small area (approximately 2 km^2) of exposed coal-bearing strata in the north-east of Scotland. A concealed extension of the coalfield continues for an unknown distance under the sea. The Brora Coalfield comprises rocks of the Brora Shale Formation, a Middle Jurassic (Bathonian to Callovian) succession (Figure 39). There has been extensive mining in the Brora Coalfield since the 16^{th} Century, from the outcrop down to about 225 m below surface. The last mine in the area closed in 1968. The principal worked seam, the Main or Brora Coal, is up to 1 m in thickness in places but is rich in pyrite and has a high ash content and it has been noted that mine waters associated with working this coal were particularly acidic. The coal showed a tendency to spontaneously combust. The only other seam of interest is the Parrot, which can sometimes be up to 1.83 m in thickness, but it is typically shaly and of inferior quality.

51.2 OPENCAST COAL MINING

There is very little opencast potential in this coalfield however, due to its limited size (<2 km^2), the presence of extensive shallow workings, the urban area of Brora and its overall low-lying position both flanking a river and close to the shoreline. It thus forms a poor prospect.

51.3 UNDERGROUND COAL MINING

There has been extensive mining of the Main Coal at Brora, from the outcrop down to about 225 m below surface. The limited size of the coalfield, lack of high quality coals and extent of old workings means there are no prospects for the further large scale underground extraction of coal in this coalfield.

51.4 COAL MINE METHANE

Due to the absence of working mines, there are no CMM prospects in the Brora Coalfield.

51.5 ABANDONED MINE METHANE

The Brora Coalfield, based on one or at most 2 seams, was worked intermittently from the sixteenth to nineteenth centuries. Mine workings are shallow and there are thought to be no AMM prospects.

52 NEW TECHNOLOGY MAP 20b (Brora)

52.1 COALBED METHANE

The VCBM prospects of this coalfield are considered likely to be extremely poor as it is shallow and the seams do not provide a thick coal resource base. The seam gas content is unknown and little is known about the permeability of the seams.

52.2 UNDERGROUND COAL GASIFICATION

The thickest coals in this coalfield are the Main (c. 1 m thick) and the Parrot (c. 1.83 m thick). Boreholes tend to be quite shallow (i.e. none greater than 105 m), but mine workings extend down to depths of about 225 m below surface with the deeper workings in the ESE. There may be a deeper extension to the coalfield to the south-east under the sea but it is doubtful whether coal will be present at depths in excess of 600 m and this, combined with the lack of thick coals, indicates that conditions suitable for UCG are probably not met in this area.

52.3 CARBON DIOXIDE SEQUESTRATION

There is no potential for CO_2 sequestration because the coal seams are deep enough and there is no potential for sequestration in combination with UCG or CBM production.

53 MINING MAP 21a (Northern Ireland)

53.1 REVIEW OF COAL IN THE AREA

53.1.1 Ballycastle Coalfield

Coal has been worked since at least 1733 in this area but there are no mining operations active at the present day. Most of the coal-bearing strata in this coalfield are of Lower Carboniferous, Brigantian age, although the upper part is thought to be of Namurian (?Pendleian-Arnsbergian) age (Sevastopulo 2001) (Figure 40). The succession is about 580 m in thickness, locally up to 700 m. The first (oldest) prominent development is the Murlough Bay Coal Group, which is present in the Cross Borehole where the total succession is 46 m thick. These coals were worked on a small scale at the Ballyvoy Colliery, where they are known as the Ballyvoy Coals. However, they are relatively thin and of poor quality. The Ballyvoy Coals were proved by drilling inland and are probably the same as those worked on the east side of Fair Head (the Murlough Bay Coal Group). The next coal (White Mine or Coal A) is separated from the Ballyvoy coals by approximately 120 m of siliciclastic sedimentary rocks. Above this is the Sronbane Coal, which lies just above the Carrickmore Marine Band. The succession above the marine band, up to the Main Coal is known as the Main Limestone Group. This contains the Main Limestone, the Limestone Coal, the Middle Till coal (0.6 m in Craigfad No.2 Bh) and the Wee Coal (0.25 m in Craigfad No.2 Bh).

The Main Coal is the most important coal in the coalfield, comprising from 1 to 1.4 m of good quality coal and has been extensively worked. The base of the Upper Carboniferous (Namurian) is taken at the position of the Main Coal. Most of the mines worked the Main Coal. From an old composite mine plan (c.1890) it looks like nearly all the Main Coal has been worked out between the cliffs and the Great Gaw - a major E-W fault that is intruded by a basaltic dyke - except for the area nearest the fault which is affected by water. At Salt Pans and Bath Lodge the Main Coal is below sea-level and is unworked in a small area only. To the east, towards Fair Head, the Main Coal occupies a small area that has been partly worked at Craigfad.

The Main Coal is separated from the next coal development, the Upper Coal Group, by the McGildowney's Marine Band. These highest coals include the Hawk's Nest Coal, the Splint Coal and the Bath Lodge Coal. The Hawk's Nest coal varies from 0.91 m in the western part of the coalfield to 1.22 m at Pollard Colliery. It is a low grade coal with high ash content. The Hawk's Nest seam has been worked to the west at Salt Pans and Bath Lodge. The Splint Coal, rarely worth working, is about 0.76 m in thickness. Further details can be obtained from the BGS Ballycastle Memoir (Wilson & Robbie 1966). The rank of these coals is 902 and Calorific value varies from 12.98 to 29.31 MJ/kg (5570 to 12579 Btu/lb), with average values of 18.64 MJ/kg (8000 Btu/lb).

53.1.2 Dungannon-Coalisland Coalfield

This coalfield covers an area of approximately 13 km^2 and comprises an area of Lower Coal Measures in the north-east, less than 2 km^2 in size, and an older, coal-bearing Namurian succession to the south-west. The coalfield is bounded to the north by the Congo Fault and the east by the Drumkee Fault (Fowler & Robbie 1961). To the north-east and south-east the Coal Measures pass unconformably below Triassic strata. Coals were worked from numerous shallow shafts and much of the coalfield down to depths of 180 m was exhausted by 1872. The main Coal Measures coals are the Derry (at base), Monkey, Beltiboy, Gortnaskea, Brackaville, Bone, Annagher, Crow and Kelly (top) (Figure 41). The most important seams for working are the Derry, Brackaville and Annagher coals. Where shallow nearly all these seams have been extensively worked in the Coalisland district. Generalised coal thicknesses are shown in Figure 41. In the Namurian succession the most important seam is the Main which has been worked at outcrop and at shallow depths at the Congo, Lewin, Dungannon (Emerald Pit) and Drumglass collieries (Fowler & Robbie 1961).

To the south-east of Coalisland, the Yard coal (1.22-1.37 m) was worked at Creenagh Colliery - it is unworked in the area of Triassic outcrop between this colliery and the Drumkee Fault where it deepens. To the north of the main Coalisland Colliery and again beneath the Triassic the coals have not been worked extensively; here the Bartley pits did not last long.

53.1.3 Annaghone Coalfield

This forms a very small faulted block 6.5 km to the north of the Coalisland Coalfield. It comprises a narrow, east-west trending strip 1.6 km long and 330 m wide and is bounded on all sides by faults (Fowler & Robbie 1961). The coalfield comprises a Lower Coal Measures succession and probably contains the upper part of the Coalisland succession (Ramsbottom et al. 1978). The coalfield has been worked out and mining had ceased before 1871. Between 1933 and 1936 some coal was worked from the Cratley Shaft. Four coals have been proved from this coalfield: The Crow, Main (=Annagher of Coalisland), Shining (=bone coal of Coalisland) and an unnamed coal. None of these coals reaches >0.3 m in thickness.

Coal Measures may well be present to the north and east of the Dungannon- Coalisland district, at considerable depths below younger sediments (D. Reay pers comm. 2003). If present south-east of the Bellmount - Drumkee Faults they will be at depths >1 km. Borehole Dernagh No. 2 shows a condensed Coal Measures-Namurian (Millstone Grit) sequence, although it is likely that some of the section has been cut out by a fault (D. Reay pers comm. 2003). Seismic lines west of Lough Neagh show a package of high amplitude reflectors possibly indicating Coal Measures in places (D. Reay pers comm. 2003). Differential Variscan inversion of individual fault blocks probably means that the Coal Measures have been completely eroded from some but preserved on others.

53.1.4 Lough Neagh Lignite Field

The Lough Neagh lignites occur within the Lough Neagh Group. The Lough Neagh Group occurs across an area of 500 km^2, of which some 300 km^2 is below Lough Neagh (Griffith et al. 1987). It has an arcuate outcrop around the western (Coagh), southern (Portadown) and eastern (Crumlin) shores of Lough Neagh (Legg 1992). It is thought to be up to 400 m in thickness and consists of interbedded sands, clays and lignites of Oligocene age (Legg 1992) resting on the Antrim Lava Group (Figure 42). The best borehole through the entire succession was drilled at Washing Bay in 1919. This proved 350 m of strata. Wright (1924) divided these into 3 units (the Upper Clays and Sands (245 m), the Middle Shales (38m) and the Lower Clays and Sands (58 m). The thickest beds of lignite (up to 2 m) were found in the lower unit. However, much thicker lignites occur in other areas.

Crumlin area: In this area three lignite seam groups occur – an upper lignite (10-43 m thick), a lower lignite (11-63 m thick) and a basal lignite (1-19 m thick). The lower lignite is the most important seam. Using the known thicknesses for the units in the group, the maximum depth of the basal lignite below surface would be 341 m. Wilkinson et al. (1980) suggest that the lignites in this area are up to 22 m in thickness. A few kilometres to the south of Crumlin (at Ballinderry-Aghalee) lignites are thin and seams are typically less than 2 m in thickness, with 5 seams known (Wilkinson et al. 1980).

East Tyrone (Coagh): Boreholes here show one seam of lignite, up to a maximum of 45 m in thickness. The maximum thickness of Lough Neagh Group sediments in East Tyrone is 283 m (unbottomed) (Legg 1992).

53.1.5 Ballymoney Lignite Field

Lignites of the Lough Neagh Group also occur in the Ballymoney area, north of the Tow Valley Fault. By 1989 a total of 92 exploration boreholes had been drilled around this area, with an estimated 620 Mt of lignite delineated. Six correlatable seams occur, over an area of 12.5 km^2 (Legg 1992). At Greenville, near Ballymoney, approximately 70 m of lignite was recorded. The maximum depth of this lignite is about 280 m (Legg 1992).

53.2 OPENCAST COAL MINING

The area of outcrop of the lignite deposits is quite extensive, thus there is potential for opencast mining of the lignites in Northern Ireland.

53.3 UNDERGROUND COAL MINING

There is no realistic potential for underground mining of the lignites in Northern Ireland and no potential for mining the hard coals, which are essentially exhausted.

53.4 COAL MINE METHANE

There are no working underground mines in Northern Ireland and so there is no CMM potential.

53.5 ABANDONED MINE METHANE

Due to the small size and age of the abandoned coalfields it is considered highly unlikely that there are any AMM prospects.

54 NEW TECHNOLOGY MAP 21b (Northern Ireland)

54.1 COALBED METHANE

The Coalisland and Ballycastle coalfields are small and heavily worked. The gas content of the seams is not known. The VCBM prospects are probably very poor because of the heavy working.

54.2 UNDERGROUND COAL GASIFICATION

Although thick seams of lignite well in excess of the 2 m cut-off are present in the area around Lough Neagh, it would appear that none of the published records indicates the lignite is present at depths in excess of 600 m. Therefore it is unlikely that the Lough Neagh lignites form a UCG resource as defined in this report. In terms of the Carboniferous aged coals, boreholes indicate that only the Annagher Coal, in the Coalisland Coalfield, forms a seam in excess of 2 m in thickness. However, none of the Westphalian and Namurian aged coalfields contain coals that occur at suitable depths for UCG.

54.3 CARBON DIOXIDE SEQUESTRATION

There is no potential for CO_2 sequestration in any of the coalfields as there is no coal recorded below 1200 m depth and no realistic CBM or UCG prospects.

55 PROPOSALS FOR FUTURE STUDIES TO IMPROVE AND EXTEND THE RESOURCE EXPLOITATION MAPS

The following topics are suggested for further study:

1. This study is being undertaken in parallel with other studies on the environmental issues of UCG and its public perception. It is becoming clear that these issues will determine the location and development of UCG trial operations in the UK. For instance, brown field sites, estuarine and near offshore locations will obviously be preferable to rural or populated areas. Separation between the coal resource and the processing plant will also have to be considered. The way forward for the onshore coal resources is to look closely at the more promising areas for UCG (both good and possibly unverifiable areas), as identified in this report, and the apply the lessons and advice that are being developed in these other projects. This exercise will further reduce the potential areas for UCG, but those that remain are more likely to be high value prospects. It is then suggested that the coal geology is revisited for these target area, with a view to identifying a new short list of sites for trial and semi-commercial UCG projects in the UK.

2. Because of the importance of the nearshore areas, a more detailed study of areas where coal-bearing strata occur, including estuaries, should be made. It is recommended that this study extends to a distance of 10 km from the shore (on the basis that the longest deviated wells drilled from onshore

into the nearshore zone are about 8 km long, at the Wytch Farm oilfield, Dorset). The underground mining data used in this project did not extend more than about 1 km offshore and these areas may be some of the most promising for the new exploitation technologies.

3. The study should be extended selectively to the UK Continental Shelf (UKCS). A study of coal resources on the UKCS has been made (see Knight et al. 1994) but this is a non-exclusive report that is not in the public domain and is not available to BGS, so no comment can be made on it here. There are extensive coal resources on the UKCS, in Carboniferous and younger strata. Whilst it is unlikely that they will be exploited more than a few kilometres from shore by any of the new technologies in the near future, it would be useful to have the resource information. Each coal-bearing formation needs to be mapped and depth and isopach maps constructed. It is recommended that the number and continuity of their contained coals be databased and an estimate of the total coal resource in each formation calculated. Other additional data such as coal quality and rank can also be gathered at this stage. A similar approach to that used here should be adopted, consisting of:

i) Creation of an offshore well database detailing the number and thickness of coal seams and the formations in which they are found. The thickness of coal seams is not known precisely in offshore wells because the only information commonly available is drill cuttings and geophysical logs. In particular there is evidence that thin seams may be under-represented on oil industry geophysical logs (Knight et al. 1996). Any information on coal quality and rank could be databased at the same time.

ii) For offshore areas, subject to copyright approval from the UK Offshore Operators Association, maps showing the locations of coal-bearing formations in the 'Lithostratigraphic Nomenclature of the UK North Sea', Lithostratigraphic Nomenclature of the UK North West Margin' and 'Lithostratigraphic Nomenclature of the East Irish Sea Basin' could be digitised. Type wells could be used to illustrate the geology and characteristics of these coal-bearing formations.

iii) Released offshore oil and gas wells could be used to make depth and isopach maps of the relevant formations. Maps should be plotted showing the cumulative thickness of coal and number of seams in each relevant formation and thus estimate the total UK offshore coal resource, its distribution and approximate depth. Sets of maps could be created using different geophysical log cutoffs for seam thickness.

iv) Other information such as water depth, licence areas, the location of offshore installations and areas where there may be potential conflicts of interest could be added to the maps.

v) A search for coal-bearing formations outside these areas of the Continental Shelf, where there are vastly fewer wells (e.g. in the English Channel), could then be conducted more economically and the data added to the database.

4. This study has identified areas with good potential for the new exploitation technologies. It is proposed that these areas be studied in more detail to properly evaluate their resource potential. This should include a detailed review of all data available in an area. In particular, a full analysis of all boreholes, rather than the selected ones used in this study should be made, and seismic datasets should be interpreted to provide information on seam dips, seam continuity and presence of faulting.

It is recommended that detailed studies should be made of the following VCBM prospects:

- The Clackmannan Syncline (Map 19b: CBM areas 1 & 2)
- The concealed extension to the Canonbie Coalfield (Map 14b)

- North Staffordshire (Map 10b: CBM areas 2 & 3)
- The Douglas Coalfield (Map 18b: CBM Area 1)
- South Lancashire (Map 10b: CBM Area 1)
- North Wales (Map 9b: CBM Areas 1-5)
- South Wales (Map 4b: all CBM areas)

All these areas apart from the Douglas Coalfield are known to have good VCBM resources. It is recommended that detailed studies should be made of the following UCG prospects:

- The Clackmannan Syncline, particularly the Firth of Forth area (Map 19b)
- The Leven Syncline, offshore from Musselburgh, East Lothian (Map 19b)
- The concealed extension to the Canonbie Coalfield (Map 14b)
- South Lancashire (Map 10b)
- North Wales (Map 9b)
- Nottinghamshire-Yorkshire (Maps 11b & 12b)
- Park prospect, North Staffordshire (Map 7b)
- East Staffordshire (Map 7b)
- Warwickshire (Maps 6b & 7b)
- Oxfordshire-Berkshire (Map 6b)
- South Wales (Map 4b)
- Kent (Map 2b)

5. Whilst a number of VCBM wells have been drilled in the UK, the general opinion is that they were not successful, although little factual data has emerged to substantiate this. Detailed study is required to identify and quantify the critical success factors required for VCBM in the UK. One control thought to be important is low seam permeability, although little quantitative data exists on the permeability of UK coal seams. Other controlling factors could include a low methane content, lack of understanding of UK coal seam reservoirs, lack of incentive for investment in field technology and differences in drilling and completion techniques. It is clear that further study is required to fully understand the controls, particularly the limiting factors, on the success of VCBM in the UK.

6. New exploratory drilling, including coring, should also be considered to provide data on rock properties, cleat orientation, methane content, coal permeability, hydrogeological conditions, sorption isotherms for single gases and gas mixtures (CO_2, CH_4, N_2) and well testing. This could be combined with a guided drilling trial, in line with the UK's Cleaner Coal Technology Programme technology target for UCG (Energy Paper 67, Summary, April 1999). This would then confirm the applicability of such a technique to UK conditions.

7. Currently, the distribution of AMM resources in this country is poorly understood, mainly because a detailed understanding of the state of mine water recovery is lacking. There are a significant number of abandoned mines and the area across which mine water is recovering or is unrecovered is fairly large, suggesting a good resource base. Hence future research should be focussed on developing a clearer picture of mine water, as well as a better understanding of the characteristics of an abandoned mine gas as a gas reservoir and developing methods for enhancing gas production in order to ensure optimum exploitation of this potentially significant resource.

8. At present the CMM resource limits have been taken as the area represented by the mining licence. However, this is only an approximation, and over estimates the resource because it assumes that coal will be extracted over the entire area of the mining licence, which is not the case. For a more detailed

calculation of the remaining CMM resources it is necessary to consider which coal seams have already been extracted, the area covered by these extractions and any proposed exploitation of remaining reserves. This would allow a more precise measure of the areas of mine workings which could then be used for a more accurate CMM resource assessment.

56 CONCLUSIONS

56.1 ABANDONED MINE METHANE

The set-up of several AMM projects in the UK in the last few years suggests that there is considerable scope for AMM development in the UK. The critical issue for abandoned mine methane projects in the UK is profitability. The industry has started to ascend a learning curve, but low electricity prices and an unfavourable fiscal regime compared to that in Germany have resulted in poor profitability. Thus there is no longer an incentive to develop further projects.

56.2 COALBED METHANE

The total VCBM resource in the UK is thought to be about 2.9 x 10^{12} m^3 (see section 9.3 above). This is a significant resource: Given annual UK natural gas consumption of approximately 100 x 10^9 m^3/year, it corresponds to about 29 years consumption.

However, it is critically important to realise that the part of this resource that realistically could be exploited in the near future is very much smaller. Even if conditions and costs in the UK coalfields were as good as those in the Black Warrior Basin of Alabama, USA, an economic VCBM resource base might require a resource density exceeding 1 x 10^6 m^3 ha^{-1} and a mean seam gas content >7.0 m^3/tonne. The UK resource with these characteristics is a little less than 1 x 10^{12} m^3. It is highly unlikely that much of this could actually be recovered, because all the indications are that low seam permeability is widespread, and there would in any case be planning constraints, etc. that would lead to less than optimal field design. Furthermore, CBM recovery is unlikely to exceed 50% even under optimal conditions. If a more realistic 3% of the dense resource could be recovered this would amount to 30 x 10^9 m^3, or four months total UK gas supply.

VCBM exploration wells have been drilled in South Wales, the Vale of Clwyd, North Wales and South Lancashire. However, significant (but not economic) gas and water production has been established at Airth in the Clackmannan Syncline. One question that needs to be answered at Airth is:

- Does the permeability of coal seams measured after stimulation at Airth reflect the true intrinsic permeability of the coal seams, or is it due in part to the fracturing of adjacent strata which are more permeable than the seams themselves?

On the basis of research and experience from decades of mine working and ventilation in the UK it seems likely that low permeability will be encountered in most, or more likely all, Carboniferous coalfields in the UK. Thus the most important questions to answer are:

- Are there ways to identify areas of better than average seam permeability?
- Are there ways to improve the *in situ* seam permeability?

- Are there ways to improve coalbed methane production from low permeability seams?

56.3 UNDERGROUND COAL GASIFICATION

The most promising areas for UCG are the Clackmannan Syncline, particularly the Firth of Forth area, the Leven Syncline, offshore from Musselburgh, East Lothian, the concealed extension to the Canonbie Coalfield, South Lancashire, North Wales, Nottinghamshire-Yorkshire, Park prospect, North Staffordshire, East Staffordshire, Warwickshire, Oxfordshire-Berkshire, South Wales and Kent. In these places coals are present at the required depths and meet the minimum thickness of 2 m. However, additional studies are required to accurately delineate these resource areas. This could include the need for further exploratory drilling. There are many issues still surrounding the process of UCG, such as environmental concerns, its economic feasibility, public acceptability, as well as technical factors such as the ability to accurately drill a deviated in-seam borehole over the required distances.

The total area where coals are suitable for gasification is approximately 4024 km^2.

Where the criteria for UCG are met, The minimum total volume of coal suitable for underground coal gasification in the UK is nearly 5700 x $10^6 m^3$ (~7 Btonnes) whereas the total volume of coal figure derived using the average coal thickness meeting the criteria per area is 12,911 x $10^6 m^3$ (~17 Btonnes) (Table 7). This represents a resource of 289 years based on the current UK coal consumption of 58 Mtonnes per year.

56.4 CARBON DIOXIDE SEQUESTRATION

Although this is a very immature technology, all concepts of carbon dioxide sequestration by sorption onto coal rely on the presence of significant coal seam permeability to inject the CO_2 into the coal at reasonable rates. Thus in a UK setting, the crucial question mark hangs over the intrinsic seam permeability, just as it does with VCBM. Furthermore, the potential for fugitive methane emissions must be controlled because molecule for molecule, methane is a greenhouse gas 7.5 times more powerful than carbon dioxide (Houghton, 1994). Other important research topics are:

- The need to have a better understanding of the theoretical basis of carbon dioxide sequestration by sorption onto coal
- Further laboratory experiments at realistic temperature and pressure conditions
- Modelling of the experiments
- Further field trials

Current research programmes such as the partially EU-funded Recopol project may go some way to answering the question of whether or how this technology could be realised in typical European Carboniferous coals.

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Mine name	Location
Ellington	North East (Northumberland)
Daw Mill	Warwickshire
Tower	South Wales
Ricall / Whitemoor	Selby (Yorkshire)
Stillingfleet / North Selby	Selby (Yorkshire)
Wistow	Selby (Yorkshire)
Hatfield	Yorkshire
Kellingley	Yorkshire
Rossington	Yorkshire
Maltby	Yorkshire
Thoresby	Nottinghamshire
Welbeck	Nottinghamshire
Harworth	Nottinghamshire
Aberpergwm*	South Wales

* smaller anthracite mine

Table 1. Underground coal mines in the UK, June 2003.

Mine	Methane capture/utilisation plant
Harworth	surface drainage plant - gas used for 14 MWe electrical power generation (2 x 2 Mwe {GT} & 10 Mwe {ST})
Kellingley	surface drainage plant - gas used for 2.8 MWe electrical power generation
Maltby	surface drainage plant; gas used for 4.2MWe electrical power generation
Riccall/Whitemoor	surface drainage plant – some gas used in boilers
Rossington	surface drainage plant
Stillingfleet/N Selby	surface drainage plant
Tower	surface drainage plant - gas used for 8.1 MWe electrical power generation
Thoresby	surface drainage plant - gas used for 2.8 MWe electrical power generation
Welbeck	surface drainage plant - gas used in boilers and for 2.8 MWe electrical power generation
Wistow	gas drained and discharged underground
Hatfield	gas drained and discharged underground

Table 2. Current CMM capture and utilisation in the UK (as of June 2003).

Area Name	Map No.	Area of Variable AMM resources (recovering minewater) (km^2)	Area of good AMM resources (unrecovered minewater) (km^2)	Unknown potential (km^2)	Total area of AMM potential (km^2) *
South Wales Coalfield	4a	531.1	16.87	900.01	547.97
Midlothian Coalfield (Scotland)	19a	132.74	0	0	132.74
Central Coalfield (Scotland)	19a	456.79	0	0	456.79
Sanquhar Coalfield (Scotland)	18a	47.76	0	0	47.76
North East Coalfield	15a	1232.37	177.95	0	1410.32
Eastern England (Nottinghamshire & Yorkshire coalfields)	11a & 12a	1507.98	666.05	0	2174.03
Bevercotes Colliery, 12km SW of Worksop	11a	8.5	0	0	8.5
Asfordby Colliery, 3km NW of Melton Mowbray	11a	55.81	0	0	55.81
South Lancashire Coalfield	10a	147.41	19.18	0	166.59
North Staffordshire Coalfield	10a	37.68	50.58	0	88.26
South Staffordshire Coalfield	7a	165.84	0	303.2	165.84
Leicestershire Coalfield	7a	89.28	0	0	89.28
Warwickshire Coalfield	7a	196.11	12.79	0	208.9
	TOTAL	4609.37	943.42	1203.21	5552.79

* Total AMM area = sum of variable and good AMM areas. Unknown AMM potential not included in this calculation

Table 3. Areas of AMM potential within the UK coalfields.

Area	Map No.	Area on Map	Area of polygon (km^2)	Total coal thickness	Clean coal thickness*	CBM range (m^3/t)	Average methane value**	Average coal density	CBM resource $10^6 m^3$	Resource density $10^6 m^3 ha^{-1}$
Kent	2		662.1	11.6	9.86	1 to 4	2.3	1.26	18919	0.29
Pembrokeshire	3		3.7	0.56	0.48	unknown		1.33	0	0.00
South Wales	4	1	58.5	20.6	17.51	19-21	20.0	1.33	27247	4.66
South Wales	4	2	16.8	15.6	13.26	21-24	22.5	1.33	6666	3.97
South Wales	4	3	127.3	13.9	11.82	16-19	17.5	1.33	35007	2.75
South Wales	4	4	244	23.8	20.23	7-10	8.5	1.33	55803	2.29
South Wales	4	5	342.4	11.5	9.78	13-16	14.5	1.33	64546	1.89
South Wales	4	6	290.2	14.5	12.33	10-13	11.5	1.33	54706	1.89
South Wales	4	7	306.6	24	20.40	4-7	5.5	1.33	45753	1.49
South Wales	4	8	451.5	14.31	12.16	unknown	12.0	1.33	87649	1.94
Bristol-Somerset	5		14	2.29	1.95	unknown	0.1	1.26	3	0.00
Newent	5		19	1.72	1.46	unknown	0.1	1.26	4	0.00
Oxfordshire	6		2610.4	12.2	10.37	0.4	0.4	1.26	13643	0.05
Midlands	7	1	136.1	30.3	25.76	7-10	9.0	1.26	39750	2.92
Midlands	7	2	163.3	40.1	34.09	4-7	6.0	1.26	42080	2.58
Midlands	7	3	187	13.2	11.22	unknown	9.0	1.26	23793	1.27
Midlands	7	4	763.7	11.8	10.03	unknown	5.0	1.26	48257	0.63
Midlands	7	5	359.7	26.9	22.87	1-4	2.0	1.26	20726	0.58
Midlands	7	6	195.4	16.3	13.86	unknown	2.0	1.26	6822	0.35
Midlands	7	8	144.8	22.7	19.30	<1	0.5	1.26	1760	0.12
Warwickshire	7	7	270.7	7.9	6.72	1.7	1.7	1.26	3894	0.14
Anglesey	8		27.9	1.4	1.19	unknown	1.0	1.26	42	0.01
Flint-Wirral	9	3	820.5	23	19.55	8	8.0	1.26	161691	1.97
North Dee	9	5	246.6	19.4	16.49	8	8.0	1.26	40990	1.66
Point of Ayr	9	1	60.5	30.2	25.67	8	8.0	1.26	15655	2.59
South Dee	9	4	383.4	21.8	18.53	8	8.0	1.26	71612	1.87
Vale of Clwyd	9	2	132.5	4	3.40	7.1	7.1	1.26	4030	0.30
Cheshire Basin	10	8	2034	48	40.80	5	5.0	1.26	522819	2.57
Lancashire	10	1	517.4	41.2	35.02	8.2	8.2	1.26	187209	3.62
Notts/Yorks	11-12	1	1980.25	23	19.55	4 to 7	5.0	1.26	243897	1.23
Notts/Yorks	11-12	2	7169.18	20.74	17.63	5	5.0	1.26	796228	1.11
Notts/Yorks	11-12	3	853.48	22	18.70	1 to 4	2.0	1.26	40219	0.47
Notts/Yorks	11-12	4	862.14	19	16.15	<1	0.5	1.26	8772	0.10
Notts/Yorks	11-12	5	156.81	14.00	11.90	<1	0.5	1.26	1176	0.07
Notts/Yorks	11-12	6	567.07	29	24.65	1 to 4	2.0	1.26	35225	0.62
Canonbie	14	2	89.3	18.8	15.98	4 to 7	6.3	1.26	11328	1.27
Cumbria	14	1	283	18.7	15.90	7 to 10	8.5	1.26	48177	1.70
Northeast	15	1	406.2	15	12.75	4 to 7	5.5	1.26	35891	0.88
Northeast	15	2	650.6	20.3	17.26	1 to 4	2.0	1.26	28290	0.43
Machrihanish	17		26.7	1.12	0.95	2	2.0	1.33	68	0.03
Ayrshire	18	2	437.7	5.6	4.76	3 - 2.8	2.8	1.26	7350	0.17
Douglas	18	1	27.1	35.9	30.52	2 - 2.8	2.8	1.26	2918	1.08
C. Glasgow	19	4	27.3	5.1	4.34	2.0	4.9	1.26	731	0.27
Clackmannan	19	1	304.3	15.8	13.43	9.0	9.0	1.26	46344	1.52
Cumbernauld	19	2	137.2	11.9	10.12	9.0	5.0	1.26	8743	0.64
Dalkeith	19	5	9.8	19.2	16.32	1.2	1.2	1.26	242	0.25
Fife/Forth	19	3	259.46	37.9	32.22	1.2	1.2	1.26	12638	0.49
Kirkintilloch	19	6	30	4.5	3.83	2.0	4.9	1.26	708	0.24
Midlothian	19	7	33.31	17.4	14.79	1.2	1.2	1.26	745	0.22
West Fife	19	8	12.1	2.78	2.36	1.2	1.2	1.26	43	0.04
** values used here may differ from published values as they refer to different geographical areas										
*clean coal thickness = total seam thickness minus 15% allowance for dirt and ash content										
Total									**2911889**	

Table 4. CBM resources and resource density in the UK calculated from resource polygons on the New Technologies maps. Map and area numbers refer specifically to the New Technologies maps that accompany this report.

Area	Map No.	Area on Map	Area of polygon (km^2)	Total coal thickness (m)	Clean coal thickness (m)*	CBM range (m^3/t)	Average methane value (m3/t)	Average coal density (g/cm3)	CBM resource $10^6 m^3$	Resource density $10^6 m^3\ ha^{-1}$
South Wales	4	1	58.5	20.6	17.51	19-21	20.0	1.33	27247	4.66
South Wales	4	2	16.8	15.6	13.26	21-24	22.5	1.33	6666	3.97
Lancashire	10	1	517.4	41.2	35.02	8.2	8.2	1.26	187209	3.62
North Staffs	7	1	136.1	30.3	25.76	7-10	9.0	1.26	39750	2.92
South Wales	4	3	127.3	13.9	11.82	16-19	17.5	1.33	35007	2.75
Point of Ayr	9	1	60.5	30.2	25.67	8	8.0	1.26	15655	2.59
South Wales	4	4	244	23.8	20.23	7-10	8.5	1.33	55803	2.29
Flint-Wirral	9	3	820.5	23	19.55	8	8.0	1.26	161691	1.97
South Wales	4	8	451.5	14.31	12.16	unknown, 12 taken	12.0	1.33	87649	1.94
South Wales	4	5	342.4	11.5	9.78	13-16	14.5	1.33	64546	1.89
South Wales	4	6	290.2	14.5	12.33	10-13	11.5	1.33	54706	1.89
South Dee	9	4	383.4	21.8	18.53	8	8.0	1.26	71612	1.87
Cumbria	14	1	283	18.7	15.90	7 to 10	8.5	1.26	48177	1.70
North Dee	9	5	246.6	19.4	16.49	8	8.0	1.26	40990	1.66
Clackmannan	19	1	304.3	15.8	13.43	9.0	9.0	1.26	46344	1.52
North Staffs	7	3	187	13.2	11.22	unknown (high)	9.0	1.26	23793	1.27
Canonbie	14	2	89.3	18.8	15.98	4 to 7	6.3	1.26	11328	1.27
Total									**978172**	
*clean coal thickness = total seam thickness minus 15% allowance for dirt and ash content										
** N.B. values used here refer to polygons on maps, not whole coalfields										

Table 5. Areas with mean seam gas content >7 m^3/tonne and resource density >1 x $10^6 m^3\ ha^{-1}$.

WELL NAME	WELL NUMBER	OPERATOR	LICENCE	LONGITUDE			LATITUDE			COUNTY	SPUD
AIRTH 1	LF/27- 2	HILLFARM	EXL237	3	47	24.000W	56	2	57.500N	FIFE	09 Aug 1993
AIRTH 2	LF/27- 3	CBM	EXL237	3	47	12.000W	56	3	13.500N	FIFE	18 Jan 1996
AIRTH 3	LF/27- 4	CBM	EXL237	3	46	50.000W	56	2	57.250N	FIFE	24 May 1996
AIRTH 4	LF/27- 5	CBM	EXL237	3	45	49.000W	56	2	45.500N	FIFE	14 Sep 1997
ARNS FARM 3	LF/27- 6	CBM	EXL237	3	44	34.000W	56	5	40.000N	CLACKMANN	19 May 1998
KEMIRA 1	LJ/22- 2	EVERGREEN	EXL203	2	47	10.000W	53	16	59.000N	CHESHIRE	21 Jan 1994
MARGAM FOREST 1	L105/12- 2	ENRON	EXL200	3	41	14.807W	51	34	41.044N	GLAM	14 Mar 1996
SEALAND 1	LJ/21- 3	EVERGREEN	EXL203	2	56	48.400W	53	12	22.900N	CHESHIRE	11 Mar 1992
SEALAND 2	LJ/21- 4	EVERGREEN	EXL203	2	57	02.700W	53	12	20.800N	CHESHIRE	25 Apr 2000
SEALAND 3	LJ/21- 5	EVERGREEN	EXL203	2	56	48.060W	53	12	22.930N	CHESHIRE	08 May 2000
SEALAND 4	LJ/21- 6	EVERGREEN	EXL203	2	56	55.500W	53	12	31.900N	CHESHIRE	13 May 2000
SEALAND 5	LJ/21- 7	EVERGREEN	EXL203	2	56	48.060W	53	12	22.930N	CHESHIRE	23 May 2000
RHUDDLAN 1	SJ07NW/28	EVERGREEN		3	28	20.49	53	16	59.87	CLWYD	Jan/Feb 1993

Table 6. Coalbed methane exploration wells in the UK

Area Name	Average thickness of coal meeting UCG criteria (m)	Area of resource (km^2)	Minimum volume of coal available for gasification (assuming a 2m seam present) ($10^6 m^3$)	Volume of coal available for gasification using average thickness of coal across area ($10^6 m^3$)
Kent	2.56	51.4	102.8	131.6
South Wales	7.13	23.7	47.4	169.0
Warwickshire	3.06	335.9	671.8	1027.9
Banbury area	3.71	42.7	85.4	158.4
Witney area	4.9	78.2	156.4	383.2
North Staffordshire	4.46	72.1	144.2	321.6
Park Prospect	6.43	93.2	186.4	599.3
Ranton, Stafford Basin	2.27	15.1	30.2	34.3
Lilleshall, Stafford Basin	4.98	6.8	13.6	33.9
Wolverhampton	4.68	30.8	61.6	144.1
SE Rugeley	5.1	24.5	49	125.0
Lichfield	6.8	84.3	168.6	573.2
NE Birmingham (Hamstead 1 Great Barr)	9.9	29.4	58.8	291.1
North Dee	3.3	63.2	126.4	208.6
S.Dee-S. Lancs	8.2	397.5	795	3259.5
West Manchester	9.1	22.12	44.24	201.3
South Notts	4.3	89.2	178.4	383.6
Newark-Gainsborough	2.42	983.2	1966.4	2379.3
North & South Selby	5.48	174.8	349.6	957.9
North & NE York	7.45	187.5	375	1396.9
Canonbie	3.9	3.89	7.78	15.2
Ayrshire	2.36	6	12	14.2
Douglas	7.5	1.3	2.6	9.8
Clackmannan	2.6	22.9	45.8	59.5
Fife	3.1	3.8	7.6	11.8
Lothian	3.8	5.6	11.2	21.3
	TOTAL	2797.71	5698.22	12911.1

Table 7. UCG resources calculated for the areas in the UK that are considered suitable.

Colliery	Seam	Mean CH_4 content ($m^3 t^{-1}$)	Formation
Cardowan	Cloven	3.6	Limestone Coal Fm
Cardowan	Kilsyth Coking	4.9	Limestone Coal Fm
Polkemmet	Wilsontown Jewel	1.5	Limestone Coal Fm

Table 8. Seam gas content measurements for the Central Coalfield, Midland Valley of Scotland (data from Creedy 1986).

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

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

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

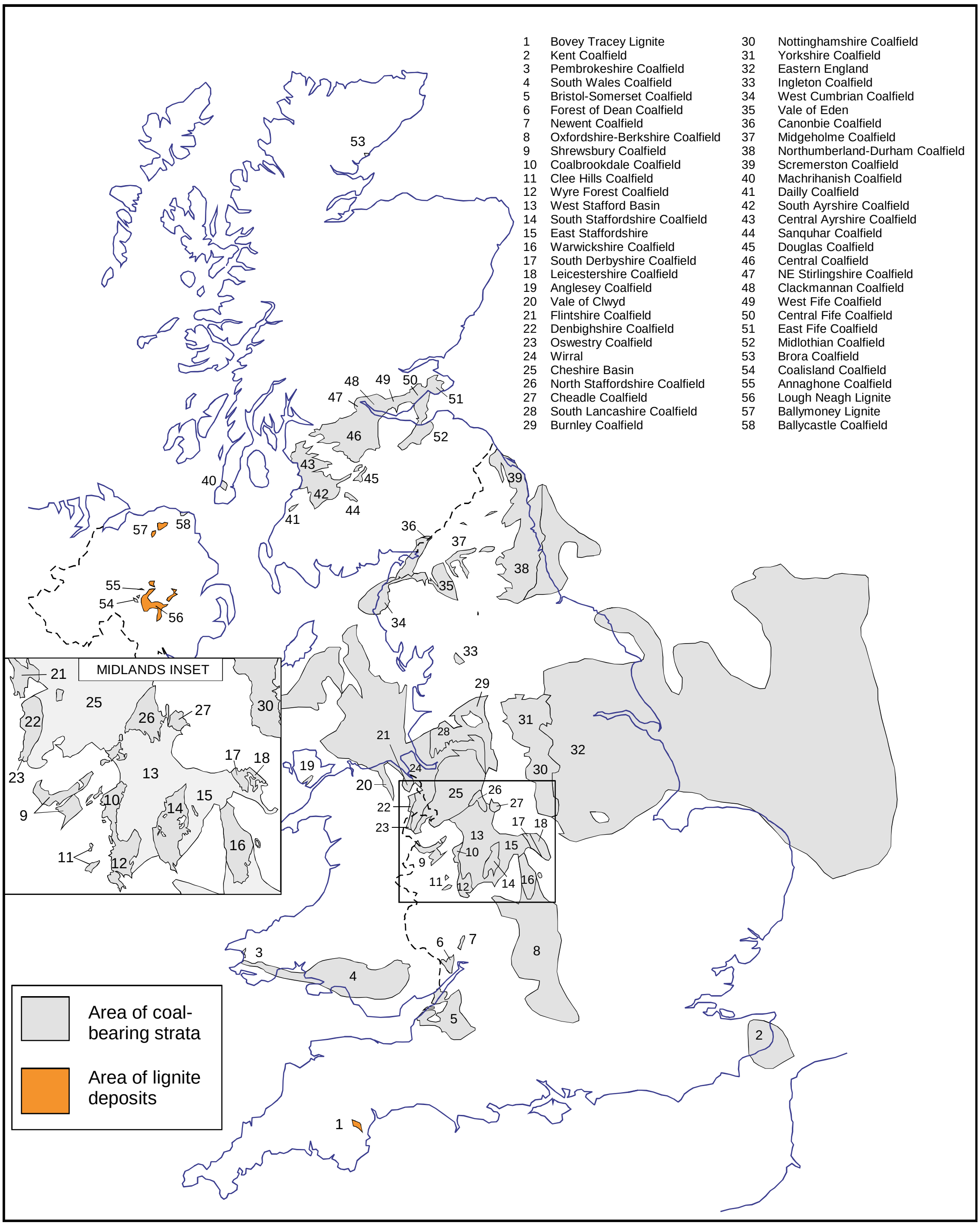


Figure 2. Map of the UK to show the location of the main coal and lignite fields studied.

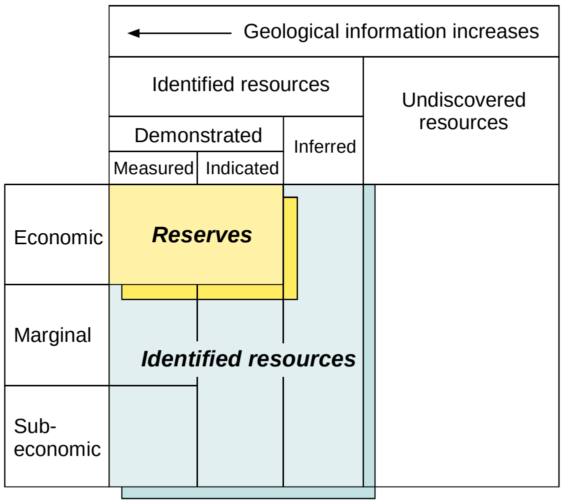


Figure 3. Diagrammatic representation of coal resources and reserves.

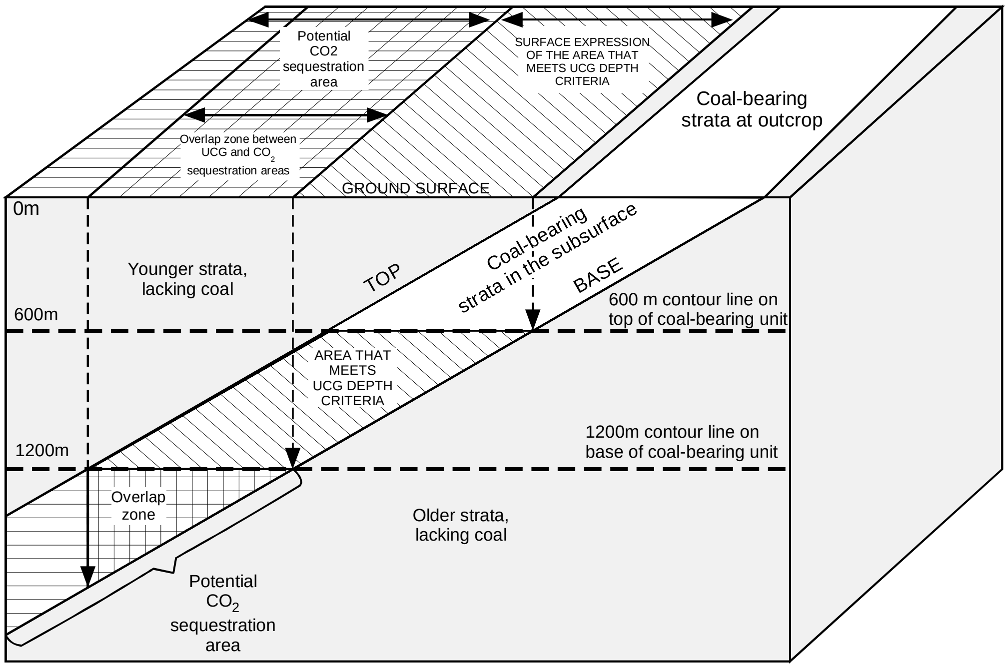


Figure 4. Block diagram of a dipping coal-bearing succession to show how the criteria for UCG and CO_2 sequestration are applied.

The UCG resource is defined as the area between the 600 and 1200 m lines. However, it is clear that in order to define the largest area suitable for UCG, the position where the 600 m line intersects the base, rather than the top, of the coal-bearing succession should be taken. Similarly the position where the 1200 m line intersects the top of the coal-bearing succession produces the greatest area for UCG. The same principle applies to CO_2 sequestration, in that the 1200 m line is taken to define the edge of the resource. If this is taken where the 1200 m line intersects the base of the coal-bearing succession then this produces a greater area suitable for CO2 sequestration. It should also be clear that this will produce an area of overlap between the two technologies.

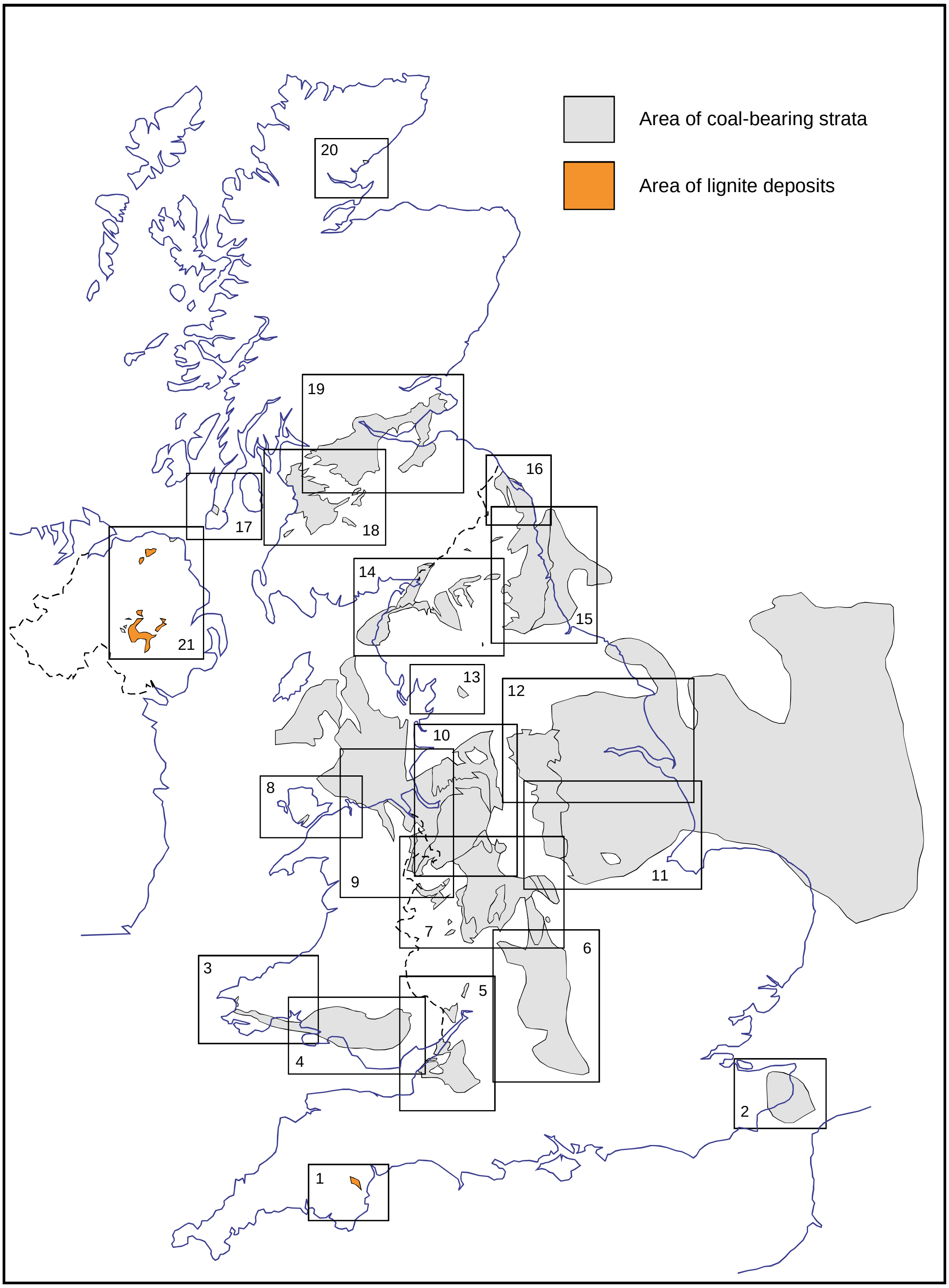


Figure 5. Map to show locations of the 1:100,000 scale mining and new technology maps produced by this study.

Figure 6. Cleat in coal. The surface facing the viewer is the face cleat. The horizontal fractures are bedding planes. The vertical fractures are the butt cleat.

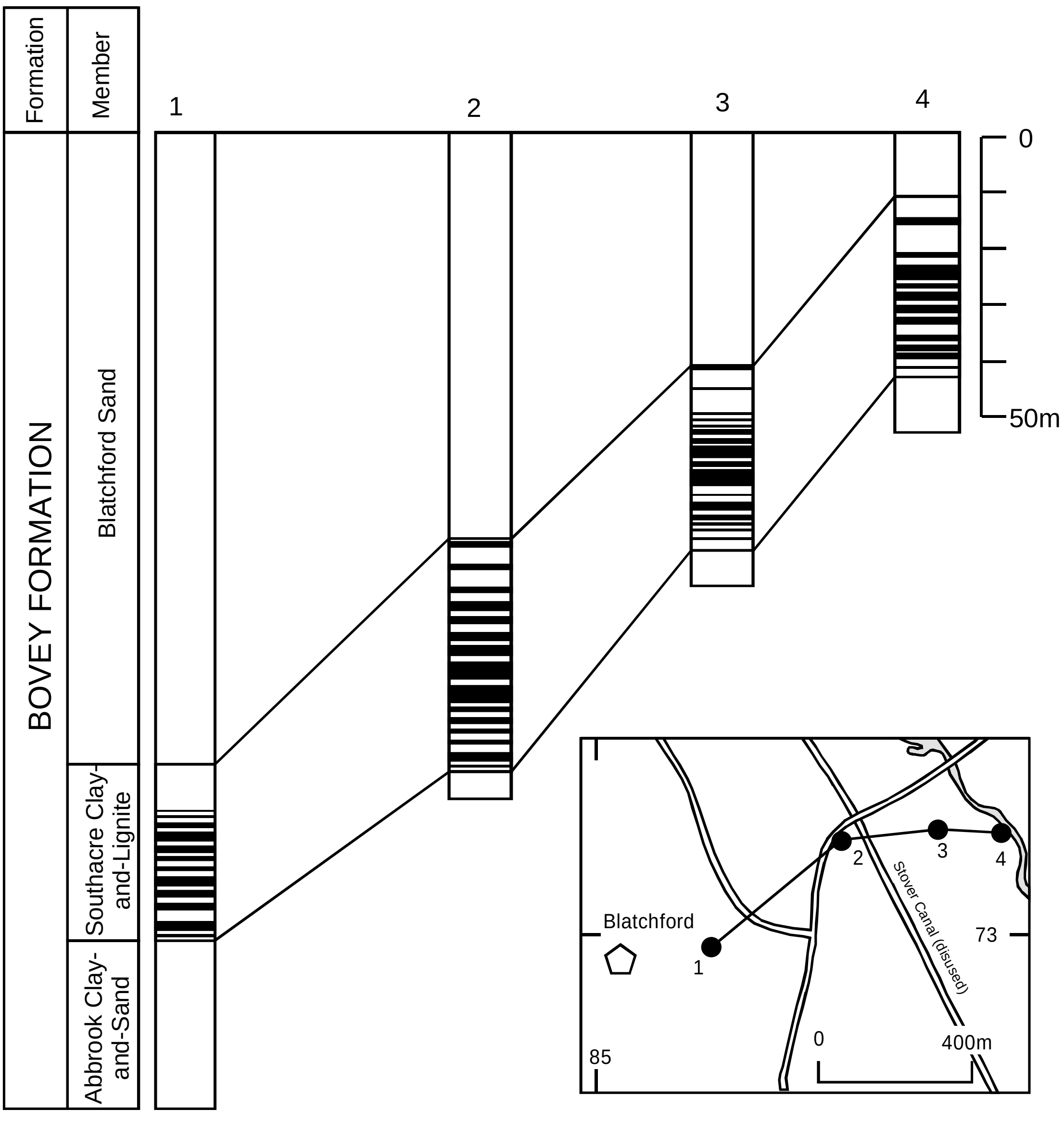


Figure 7. Cross section through part of the Bovey Tracey Formation to illustrate the thickness and distribution of the main lignite-bearing unit (redrawn with modifications from Selwood et al. 1984). Lignite beds are drawn as thicker black lines.

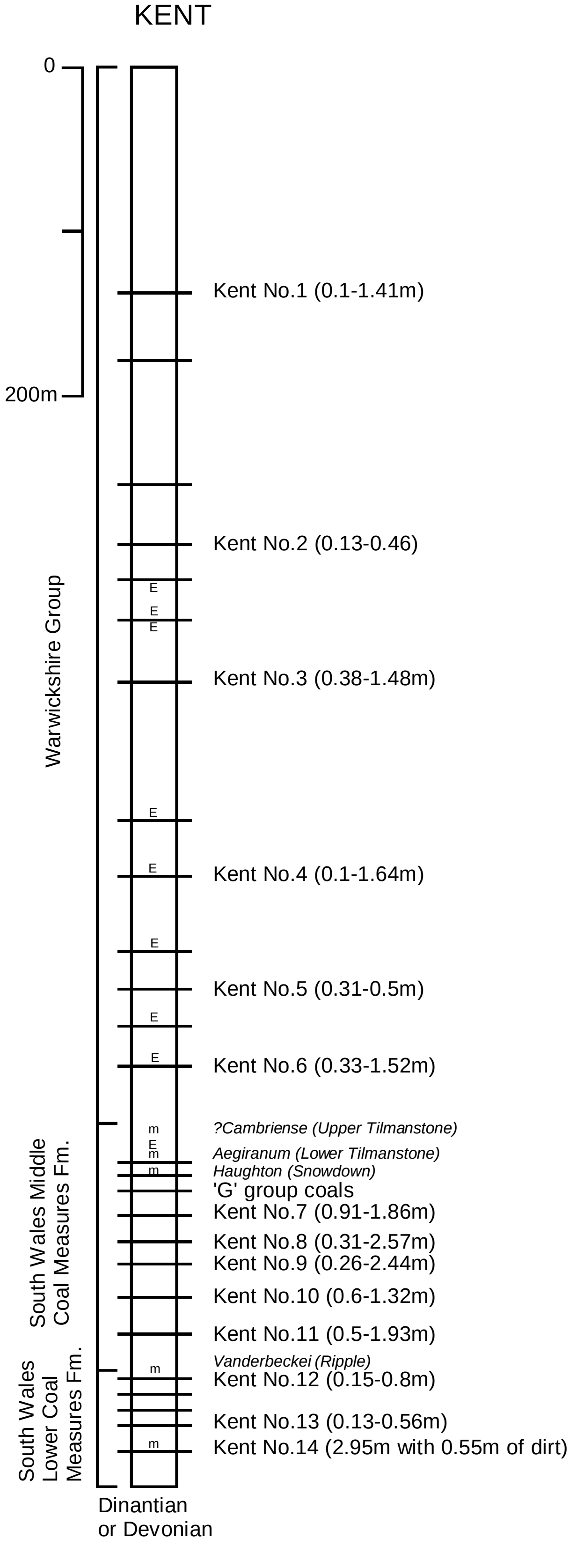


Figure 8. Stratigraphy of the main coal-bearing stratigraphic succession in the Kent Coalfield. Main seam names and thicknesses, where known, are labelled. m=marine band; E=Estheria band. Italicised text represent marine (or Estheria) band names.

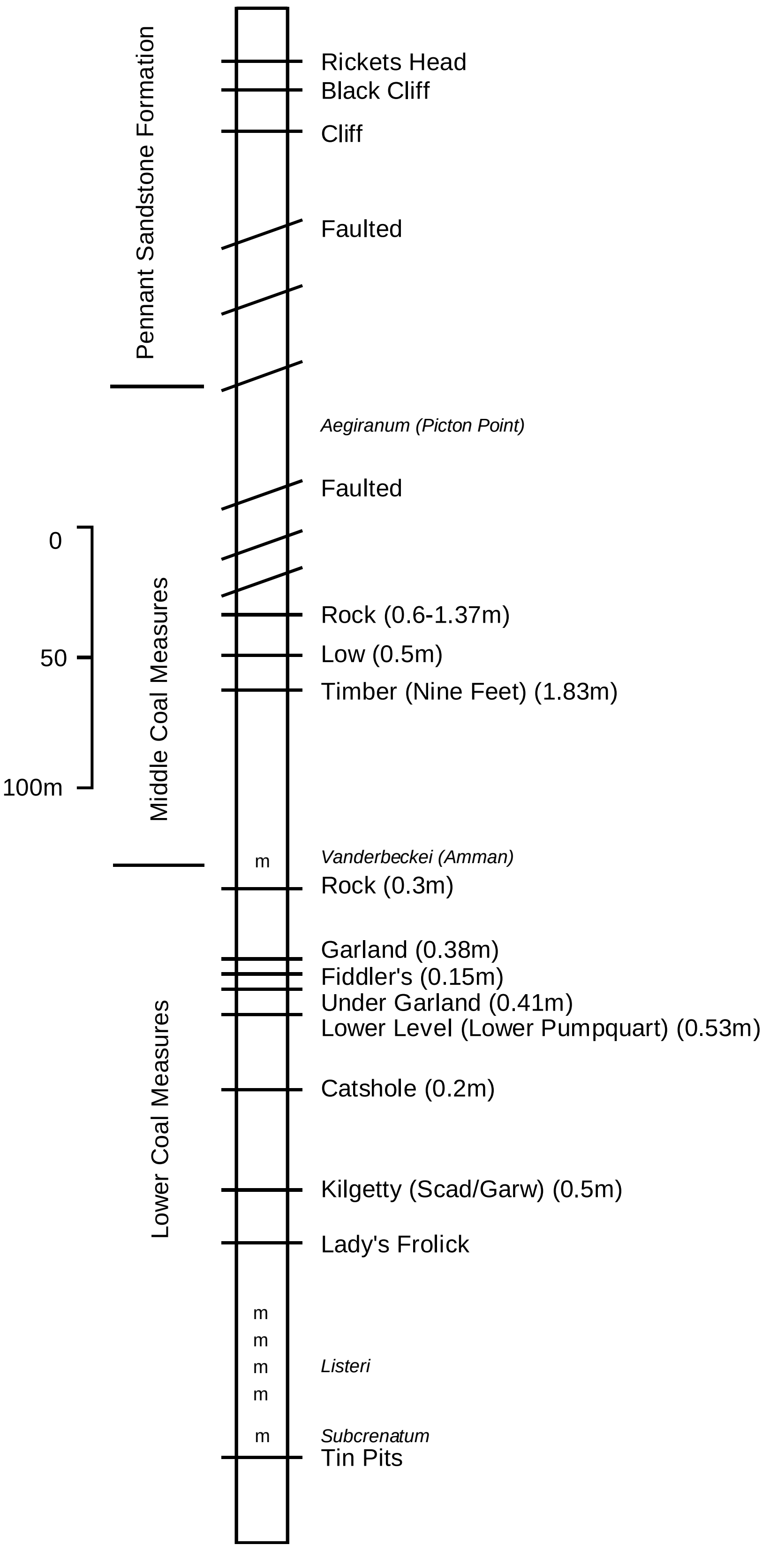


Figure 9. Stratigraphy of the main coal-bearing stratigraphic succession in the Pembrokeshire Coalfield. Main seam names and thicknesses, where known, are labelled. m=marine band; E=Estheria band. Italicised text represent marine (or Estheria) band names.

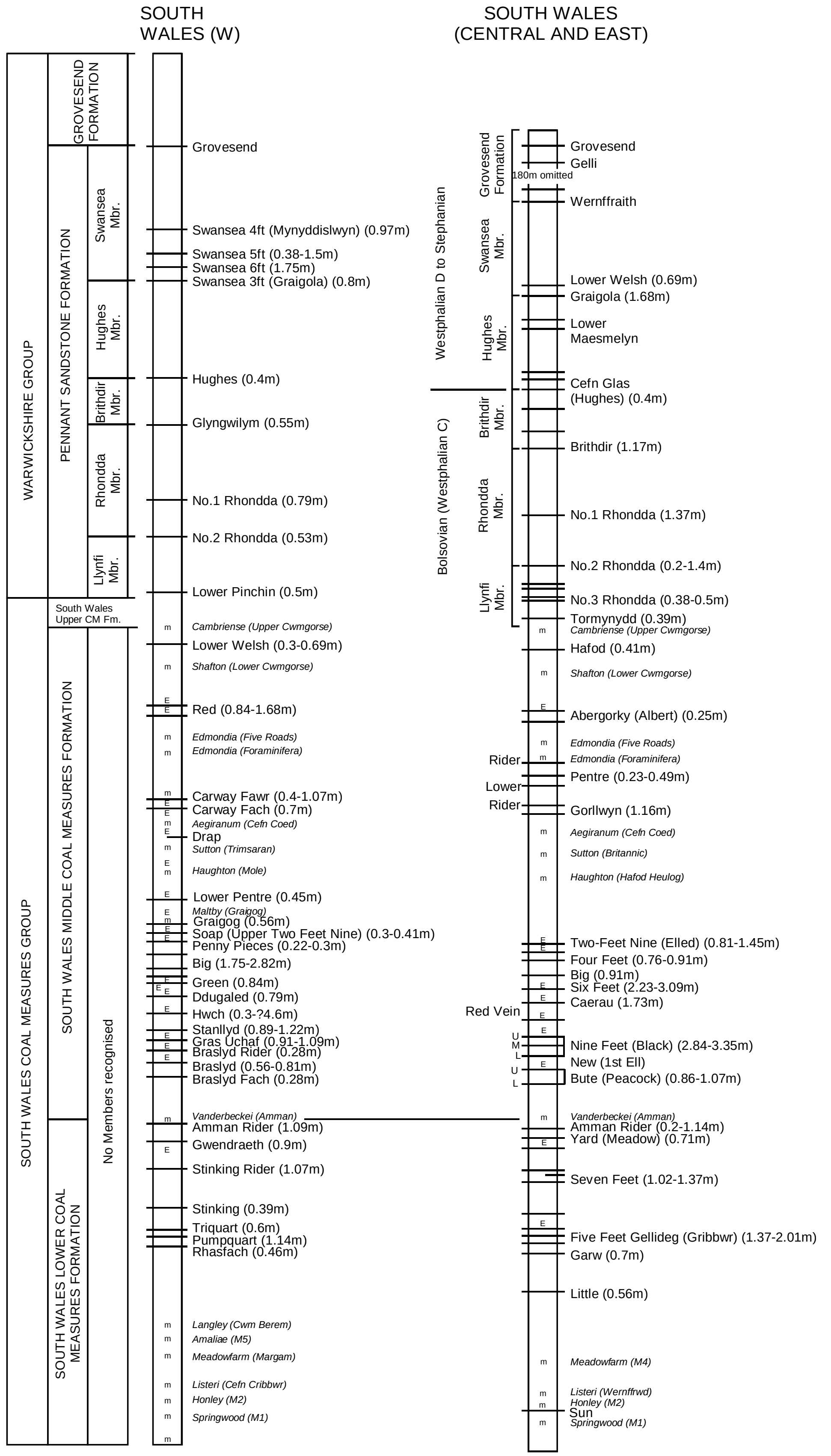


Figure 10. Stratigraphy of the main coal-bearing stratigraphic succession in the South Wales Coalfield. Main seam names and thicknesses, where known, are labelled. m=marine band; E=Estheria band. Italicised text represent marine (or Estheria) band names.

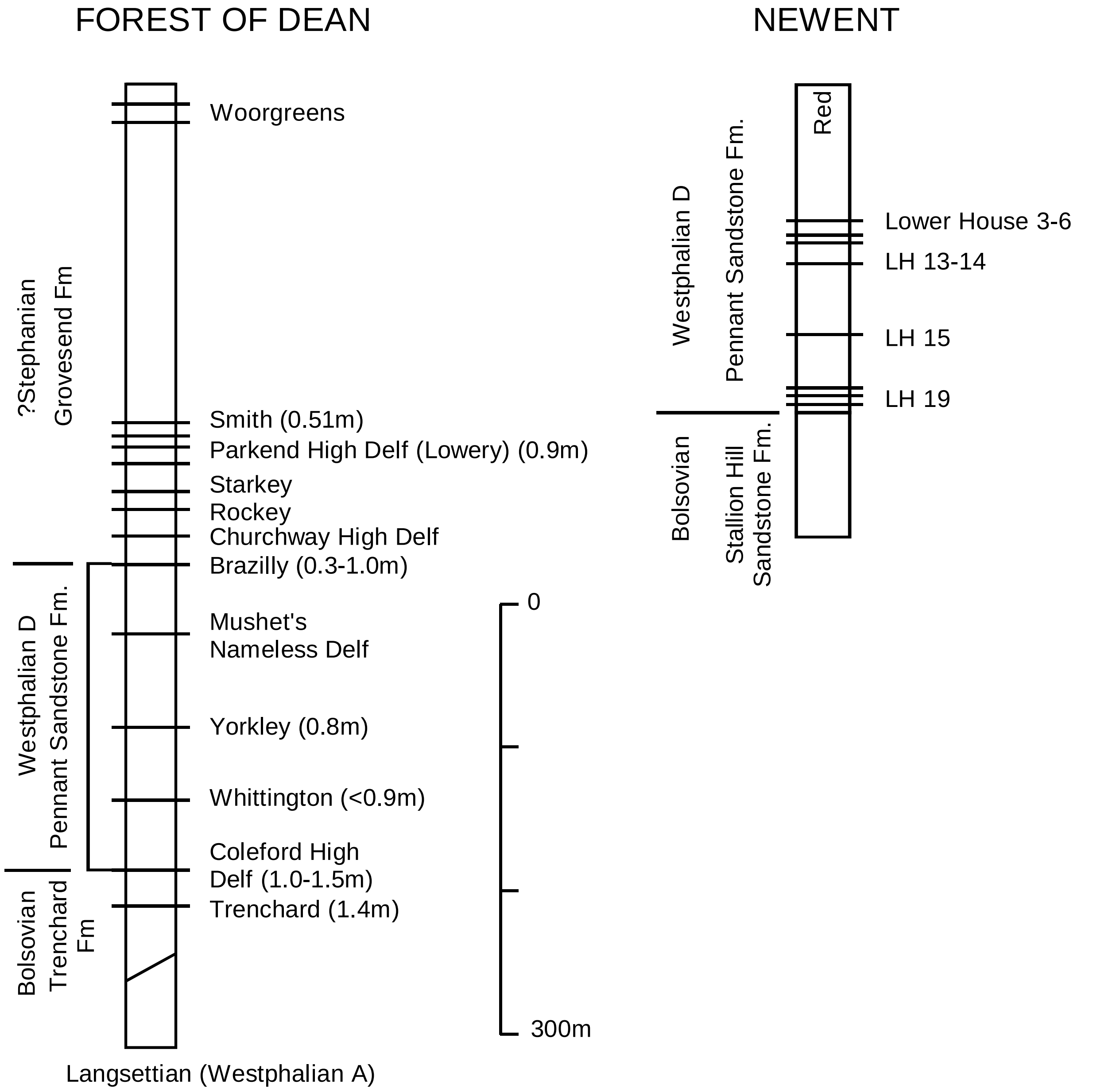


Figure 11. Stratigraphy of the main coal-bearing stratigraphic succession in the Forest of Dean and Newent coalfields. Main seam names and thicknesses, where known, are labelled. m=marine band; E=Estheria band. Italicised text represent marine (or Estheria) band names.

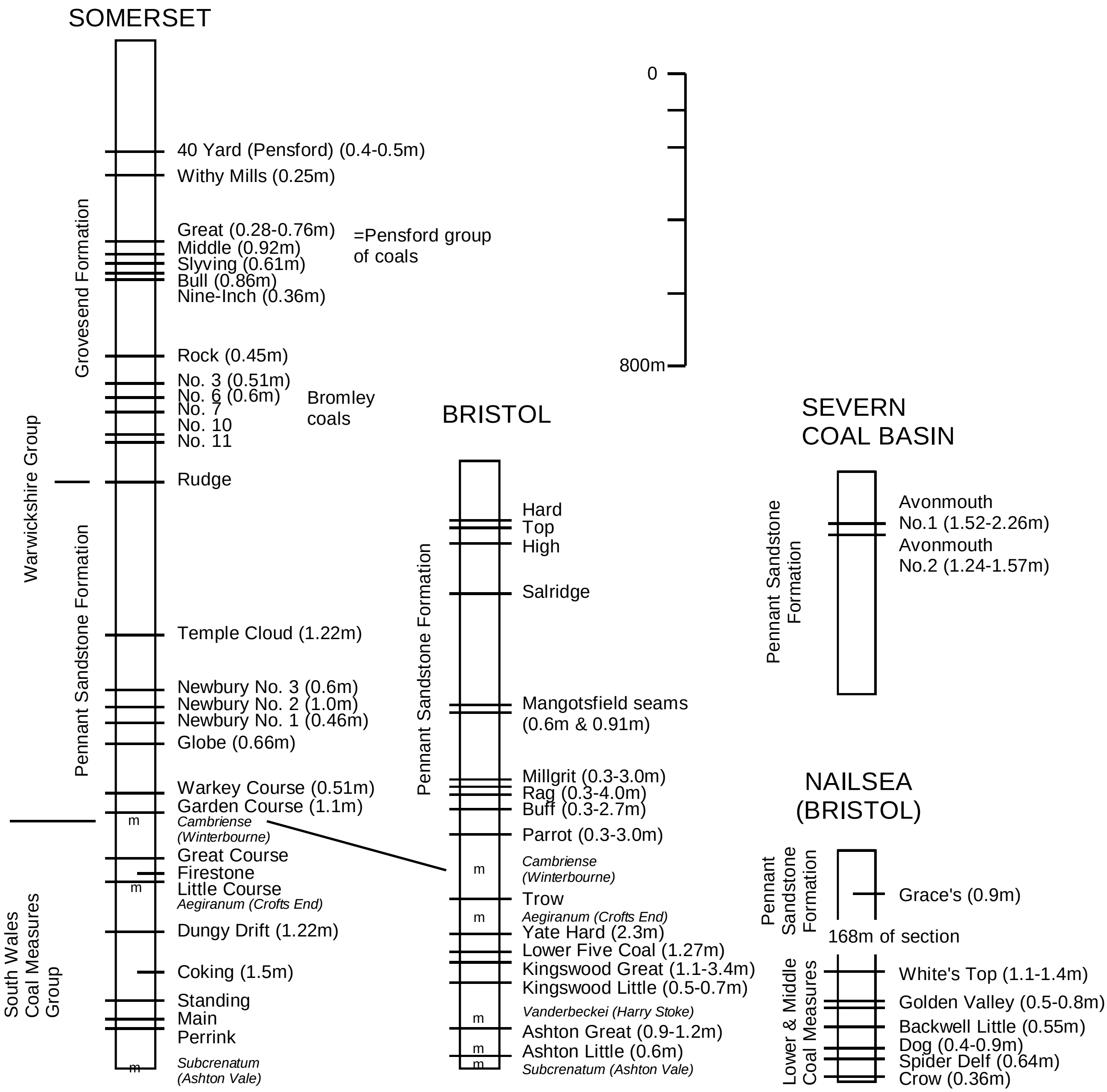


Figure 12. Stratigraphy of the main coal-bearing stratigraphic succession in the Bristol-Somerset Coalfield. Main seam names and thicknesses, where known, are labelled. m=marine band; E=Estheria band. Italicised text represent marine (or Estheria) band names.

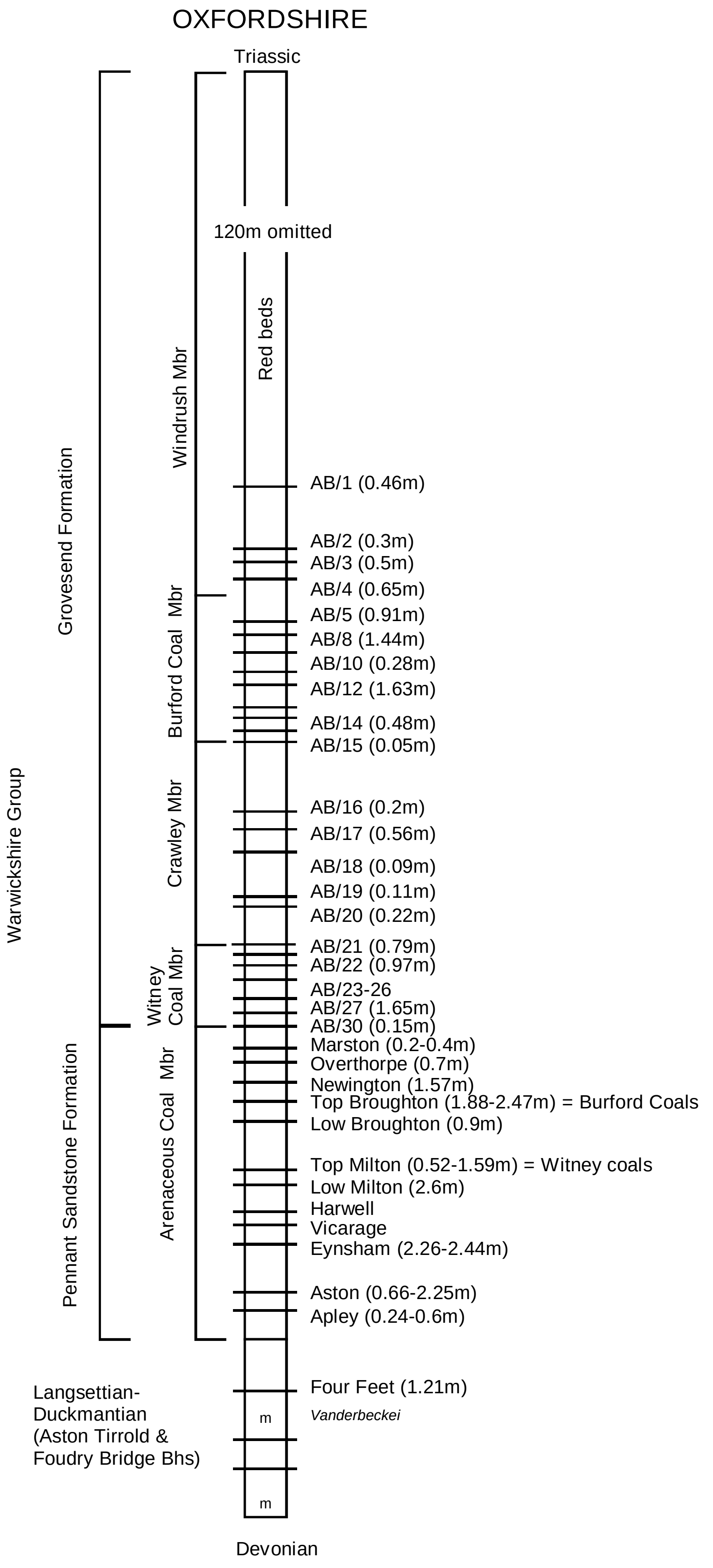


Figure 13. Stratigraphy of the main coal-bearing stratigraphic succession in the Oxfordshire-Berkshire Coalfield. Main seam names and thicknesses, where known, are labelled. m=marine band; E=Estheria band. Italicised text represent marine (or Estheria) band names.

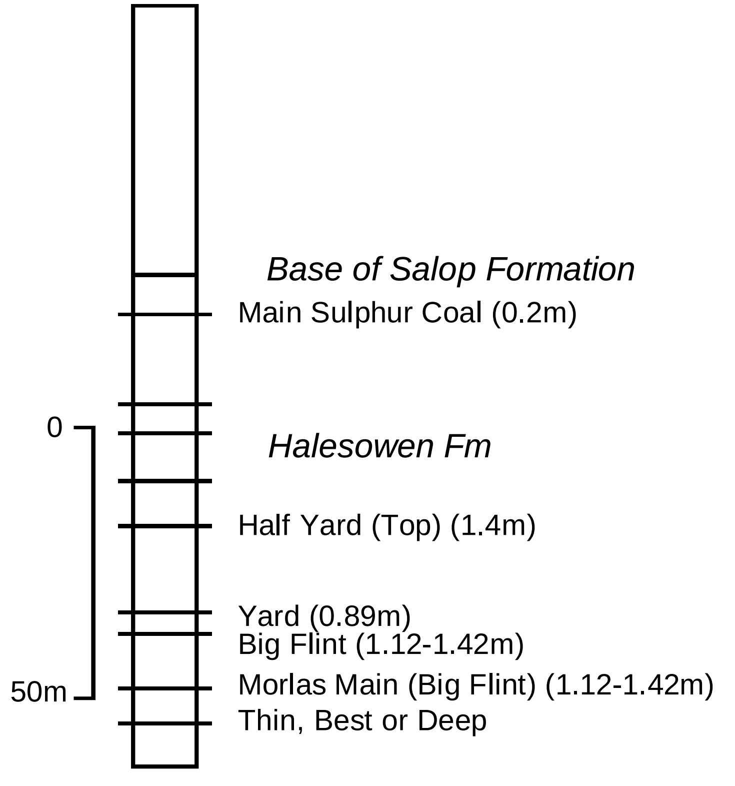


Figure 14. Stratigraphy of the main coal-bearing stratigraphic succession in the Shrewsbury Coalfield. Main seam names and thicknesses, where known, are labelled.

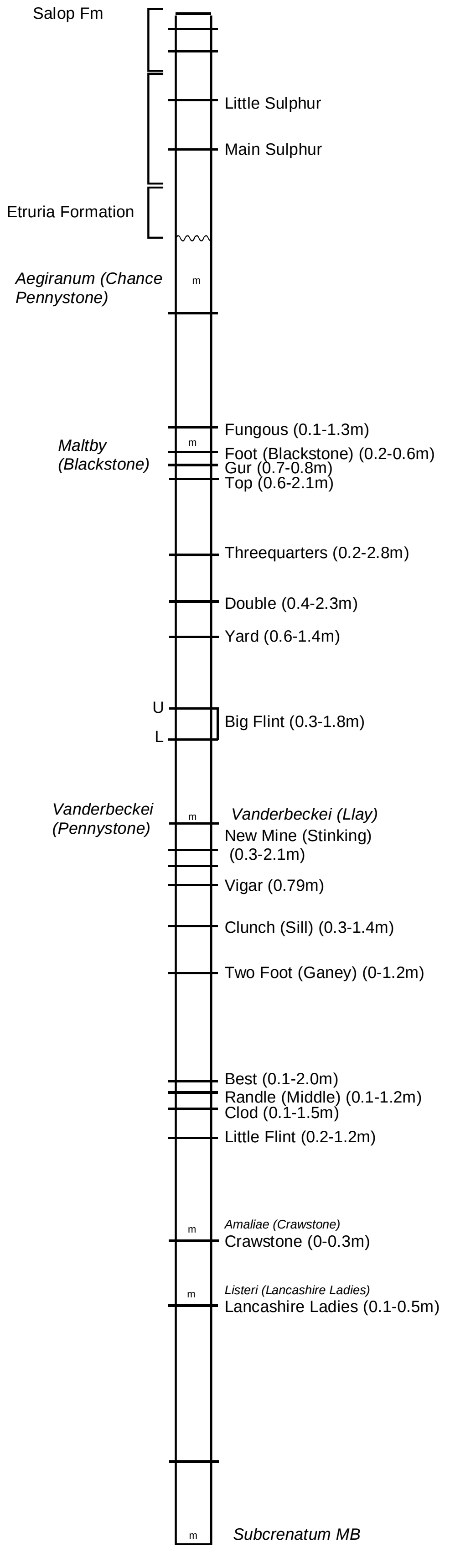


Figure 15. Stratigraphy of the main coal-bearing stratigraphic succession in the Coalbrookdale Coalfield and West Staffordshire area. Main seam names and thicknesses, where known, are labelled. m=marine band; E=Estheria band. Italicised text represent marine (or Estheria) band names.

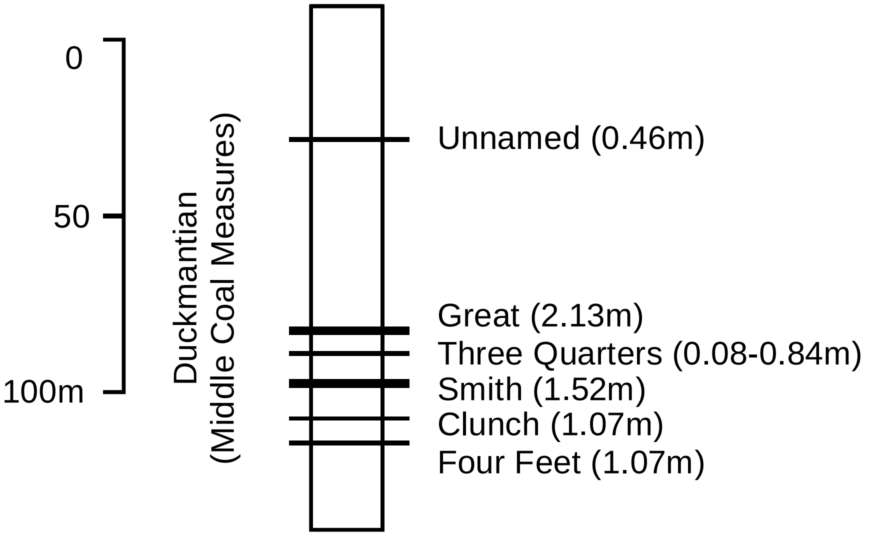


Figure 16. Stratigraphy of the main coal-bearing stratigraphic succession in the Clee Hills Coalfield. Main seam names and thicknesses, where known, are labelled.

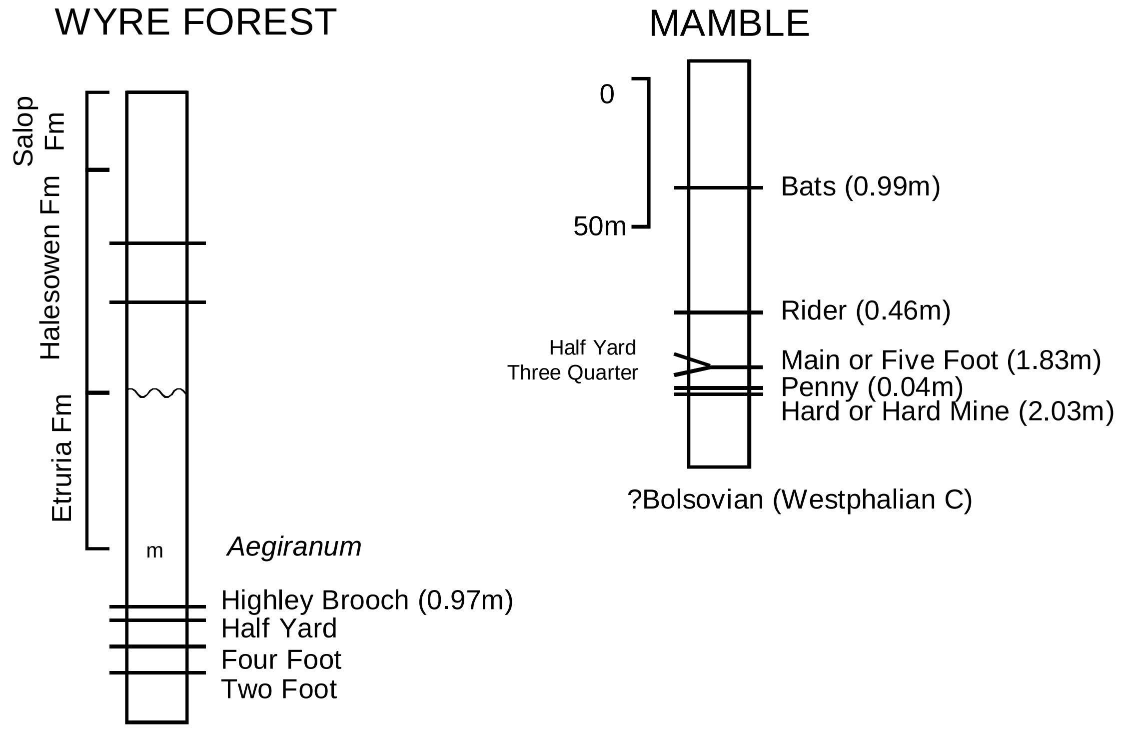


Figure 17. Stratigraphy of the main coal-bearing stratigraphic succession in the Wyre Forest and Mamble coalfields. Main seam names and thicknesses, where known, are labelled. m=marine band; E=Estheria band. Italicised text represent marine (or Estheria) band names.

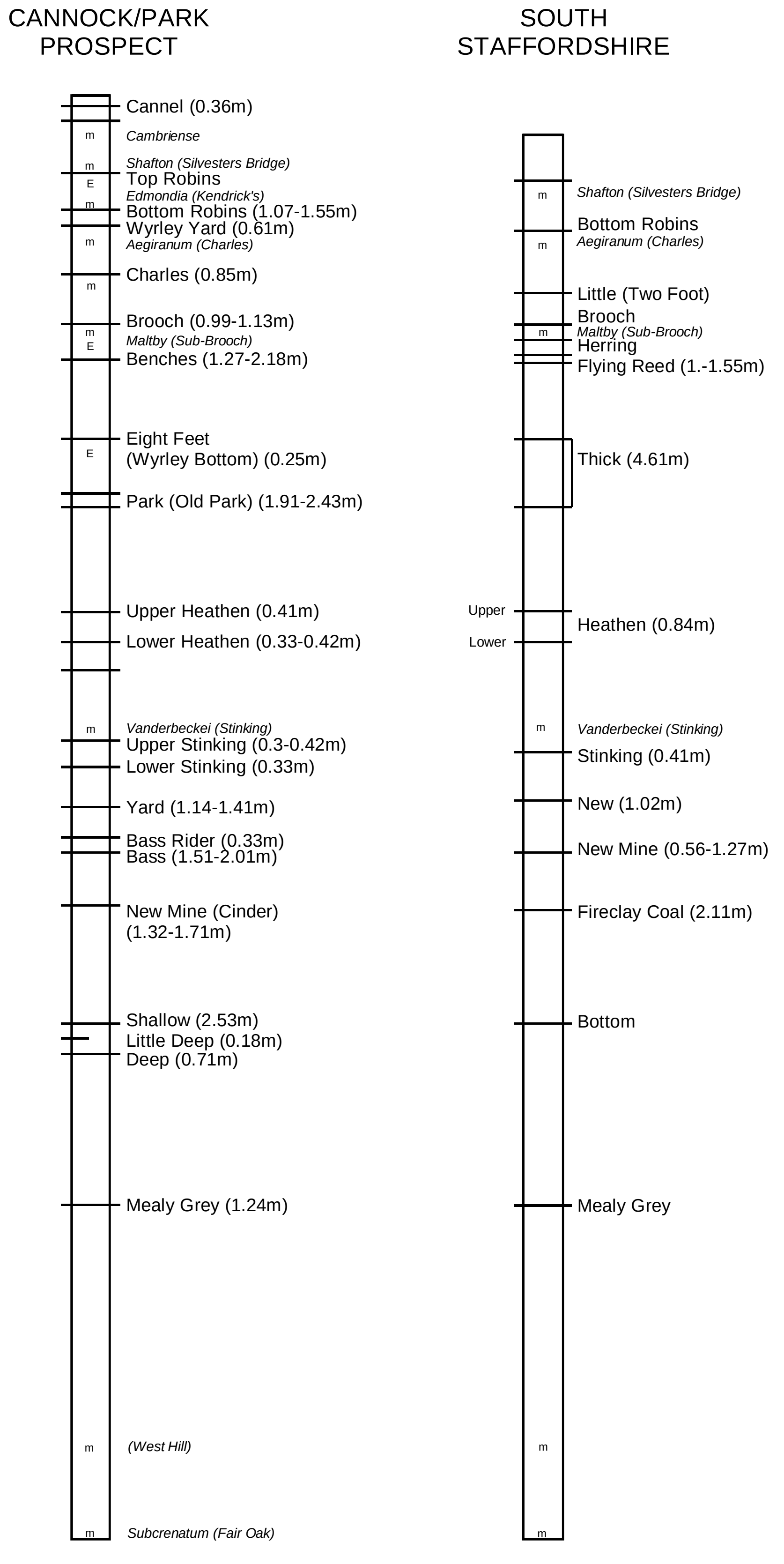


Figure 18. Stratigraphy of the main coal-bearing stratigraphic succession in the South Staffordshire Coalfield and Park Prospect area. Main seam names and thicknesses, where known, are labelled. m=marine band; E=Estheria band. Italicised text represent marine (or Estheria) band names.

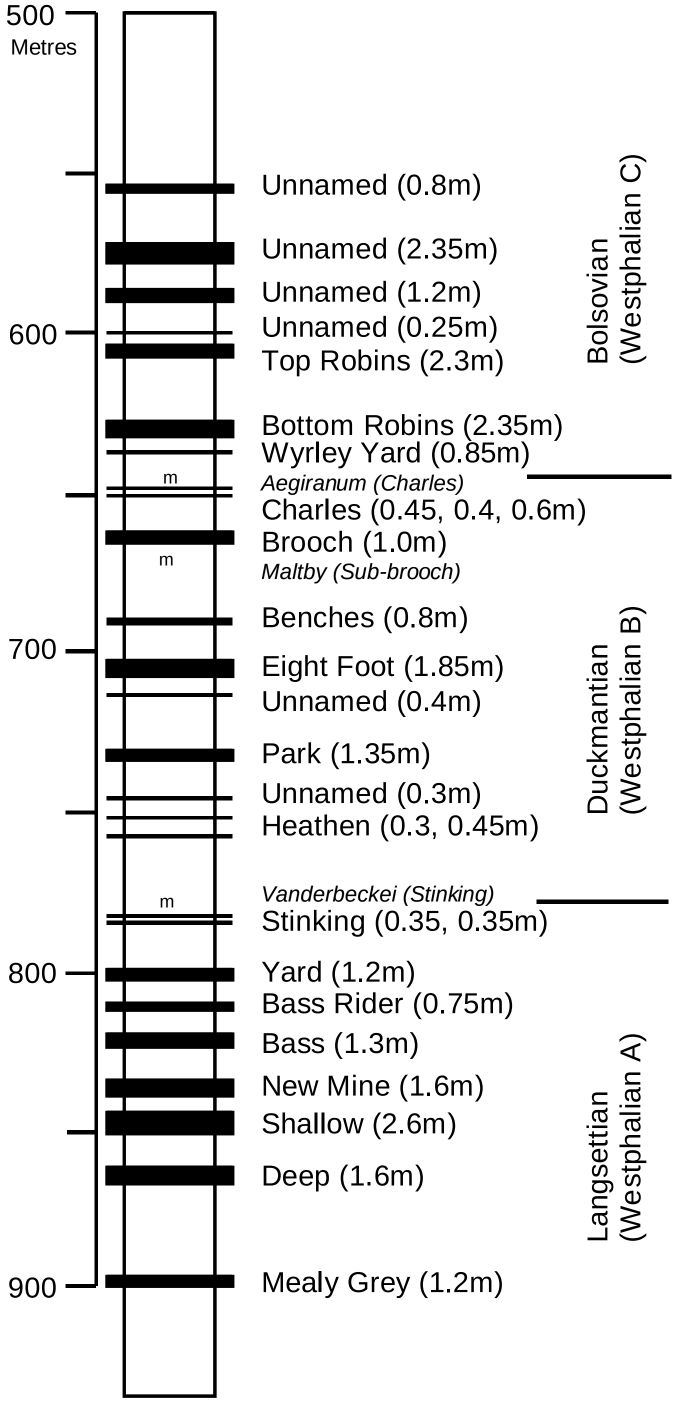


Figure 19. Stratigraphy of the main coal-bearing stratigraphic succession in the East Staffordshire area. Main seam names and thicknesses, where known, are labelled. m=marine band; E=Estheria band. Italicised text represent marine (or Estheria) band names.

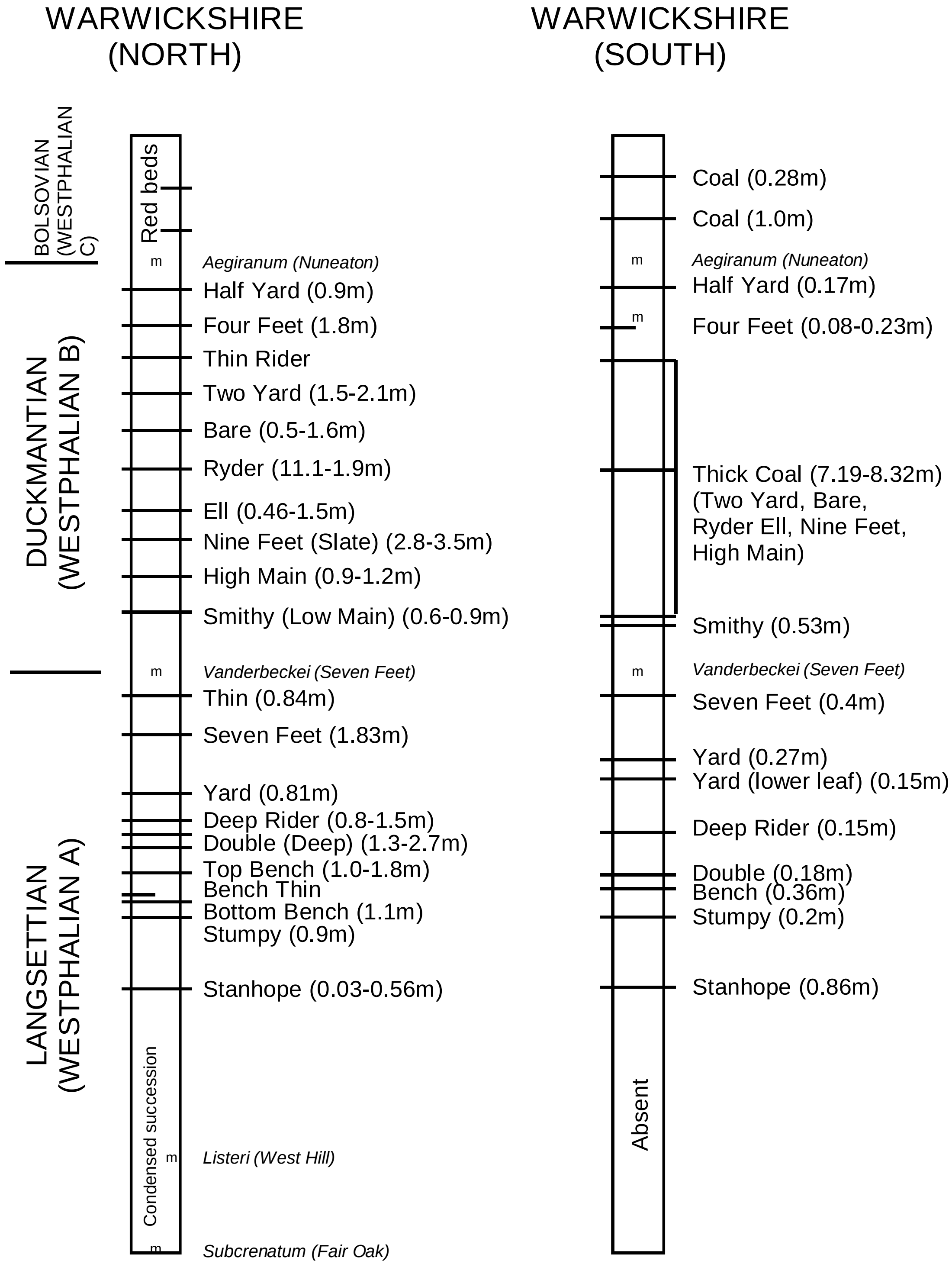


Figure 20. Stratigraphy of the main coal-bearing stratigraphic succession in the Warwickshire area. Main seam names and thicknesses, where known, are labelled. m=marine band; E=Estheria band. Italicised text represent marine (or Estheria) band names.

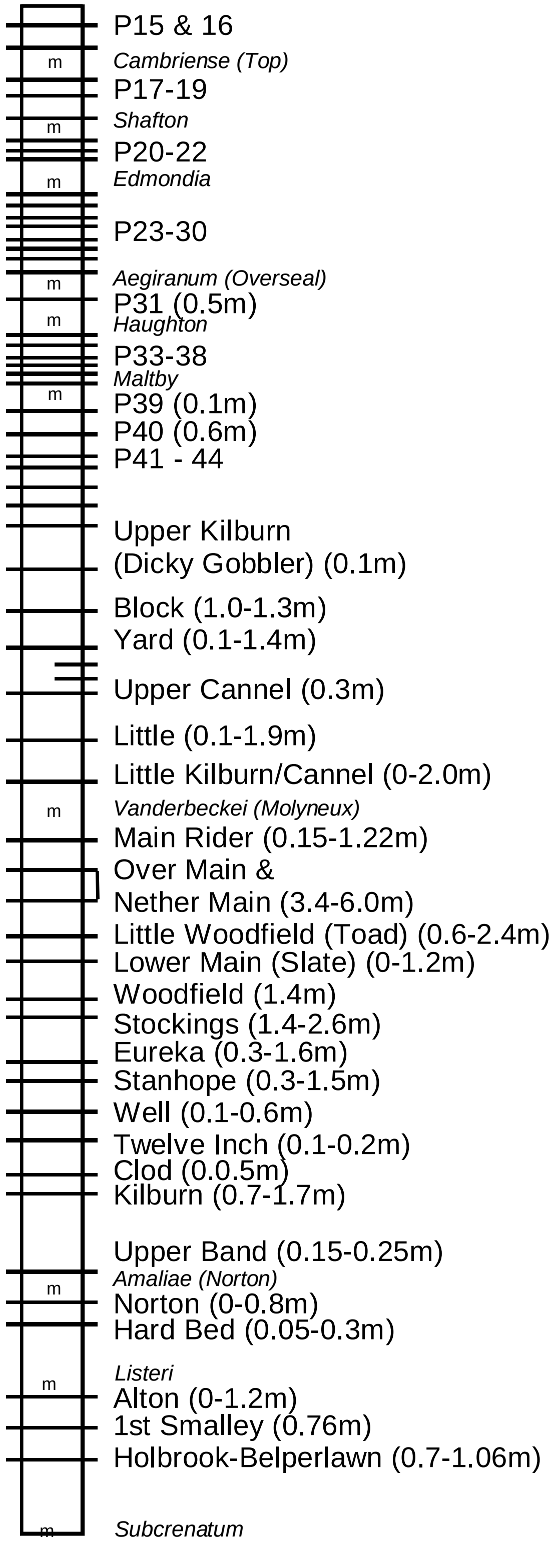


Figure 21. Stratigraphy of the main coal-bearing stratigraphic succession in the South Derbyshire Coalfield. Main seam names and thicknesses, where known, are labelled. m=marine band; E=Estheria band. Italicised text represent marine (or Estheria) band names.

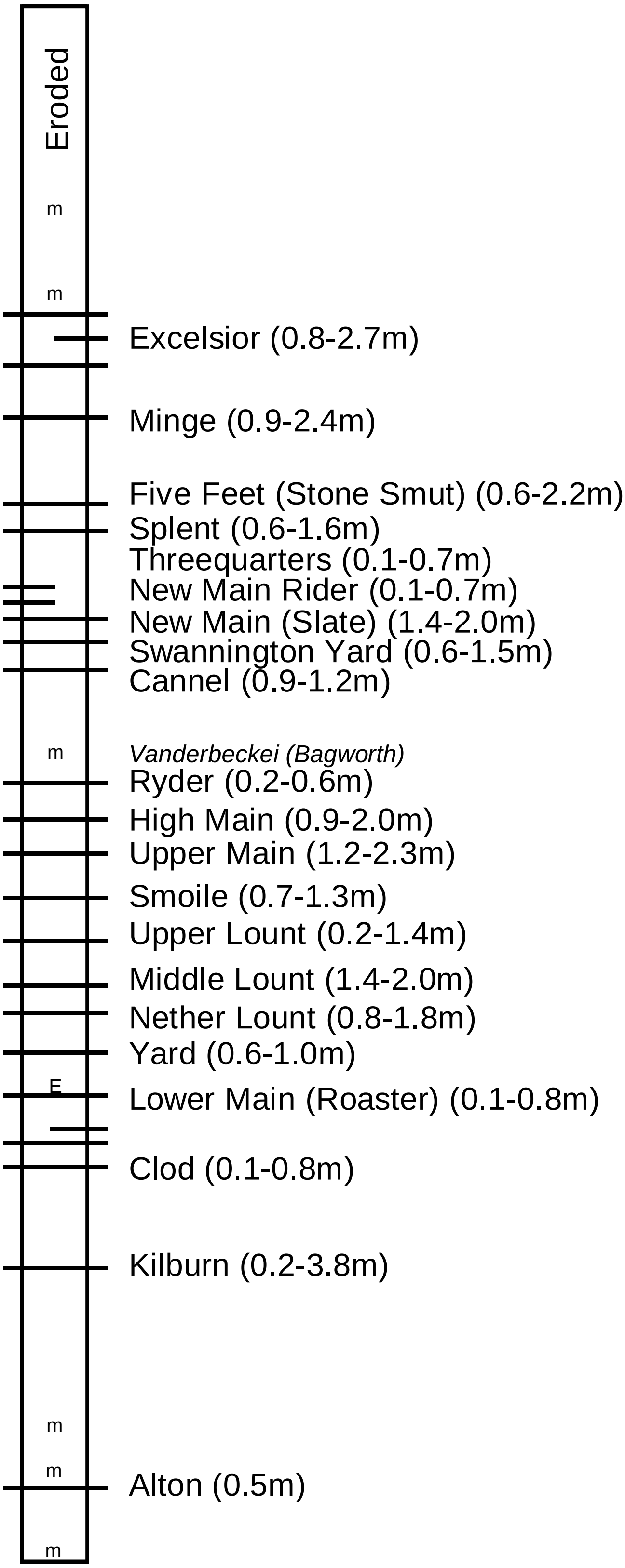


Figure 22. Stratigraphy of the main coal-bearing stratigraphic succession in the Leicestershire Coalfield. Main seam names and thicknesses, where known, are labelled. m=marine band; E=Estheria band. Italicised text represent marine (or Estheria) band names.

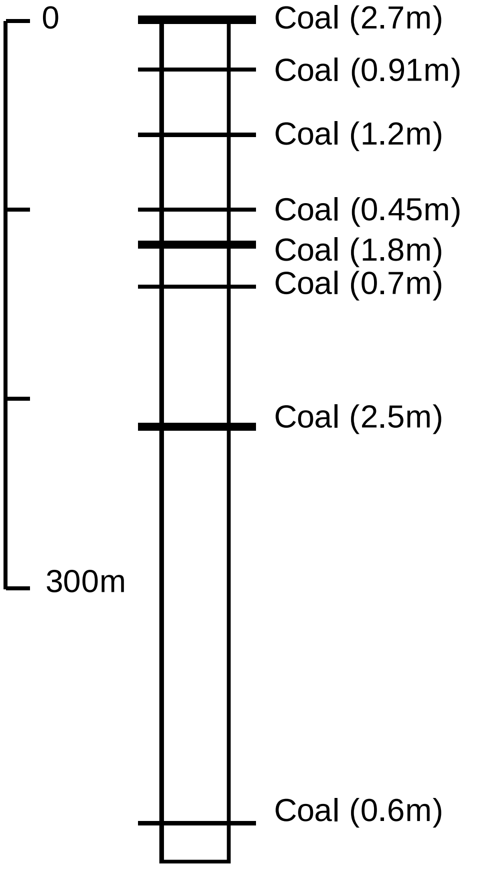


Figure 23. Stratigraphy of the main coal-bearing stratigraphic succession in the Anglesey Coalfield. Main seam names and thicknesses, where known, are labelled.

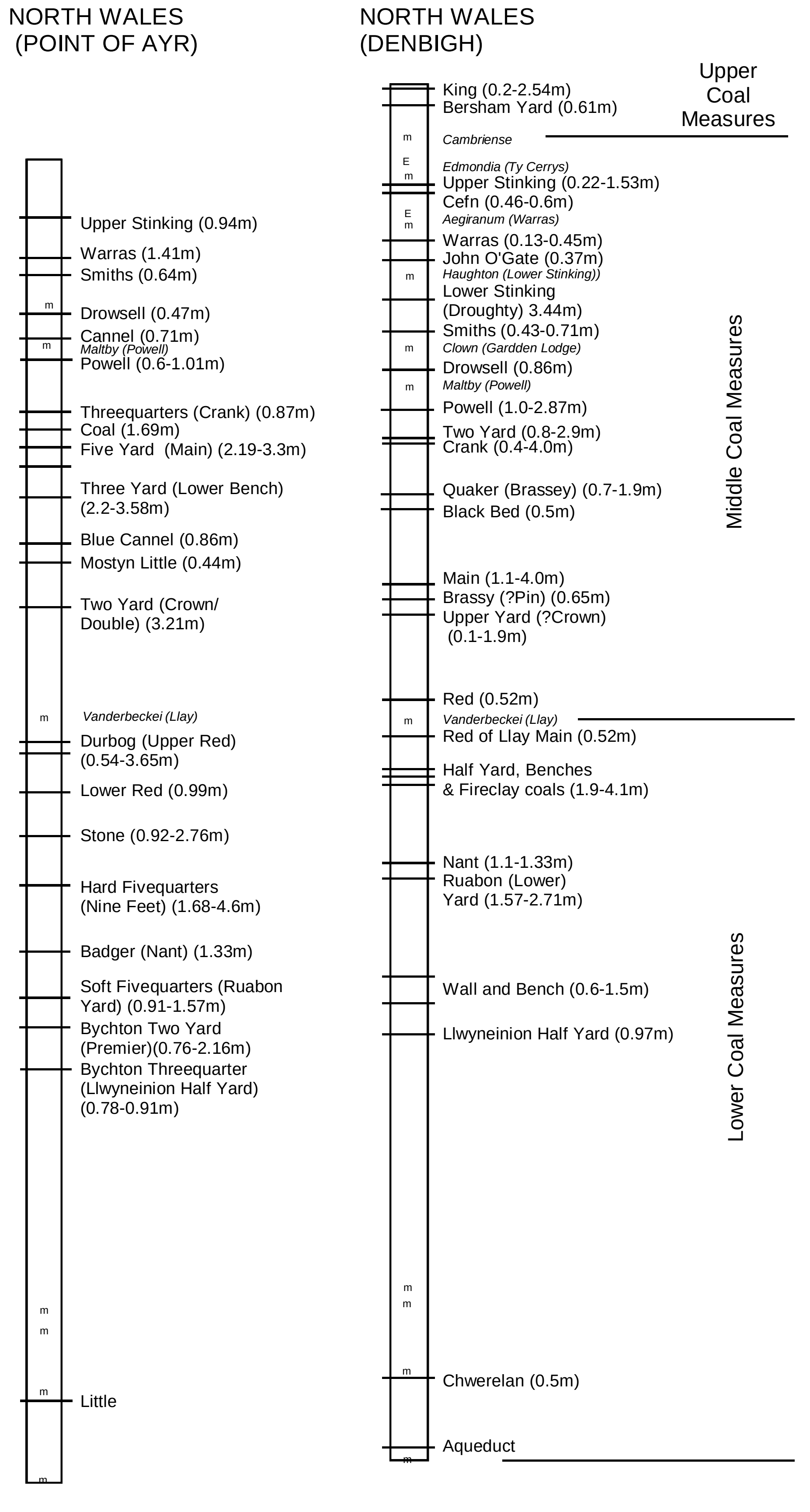


Figure 24. Stratigraphy of the main coal-bearing stratigraphic succession in the North Wales Coalfield. Main seam names and thicknesses, where known, are labelled. m=marine band; E=Estheria band. Italicised text represent marine (or Estheria) band names.

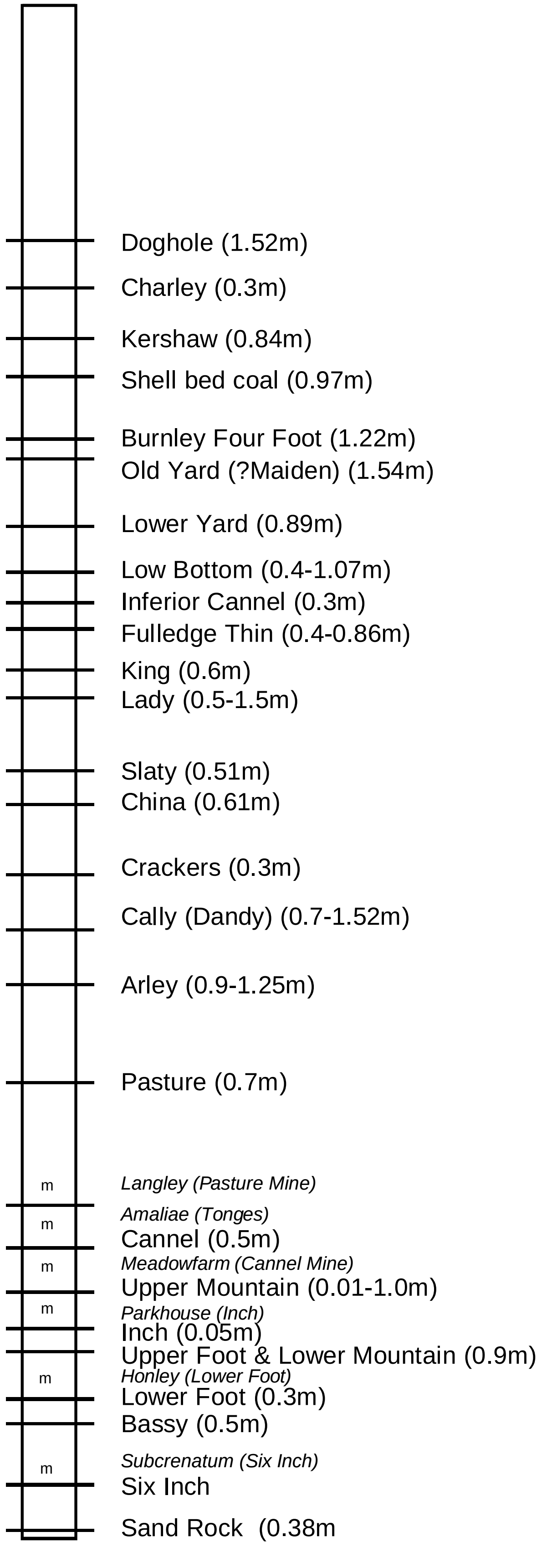


Figure 25. Stratigraphy of the main coal-bearing stratigraphic succession in the Burnley Coalfield. Main seam names and thicknesses, where known, are labelled. m=marine band; E=Estheria band. Italicised text represent marine (or Estheria) band names.

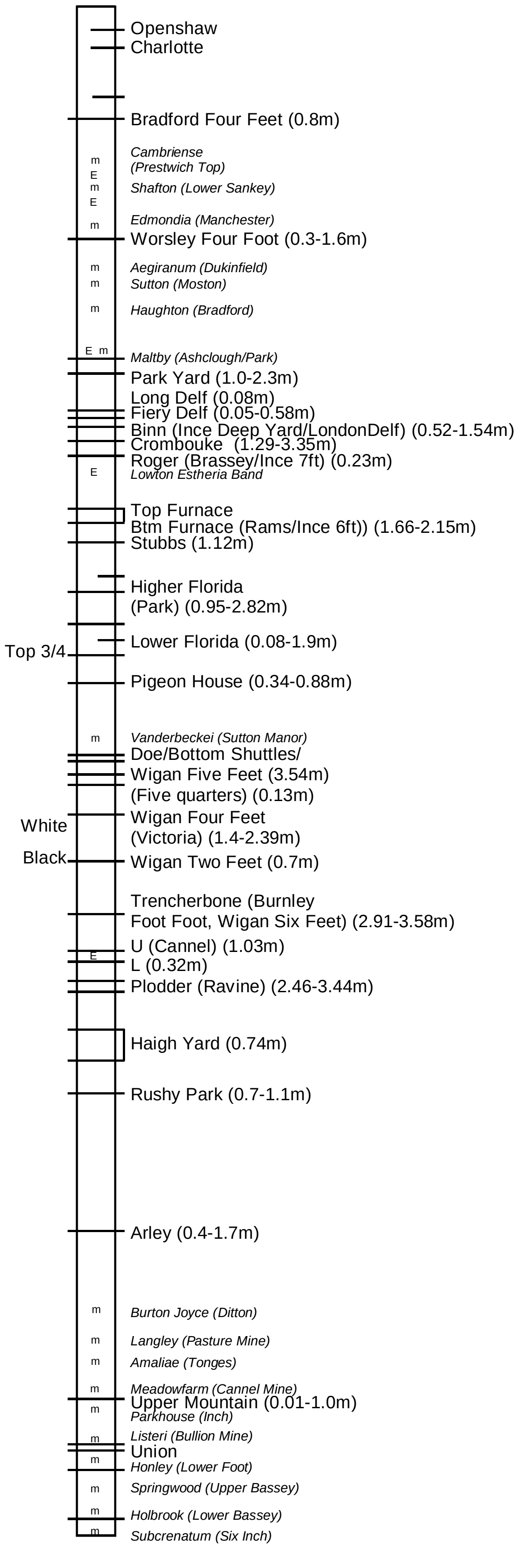


Figure 26. Stratigraphy of the main coal-bearing stratigraphic succession in the South Lancashire Coalfield. Main seam names and thicknesses, where known, are labelled. m=marine band; E=Estheria band. Italicised text represent marine (or Estheria) band names.

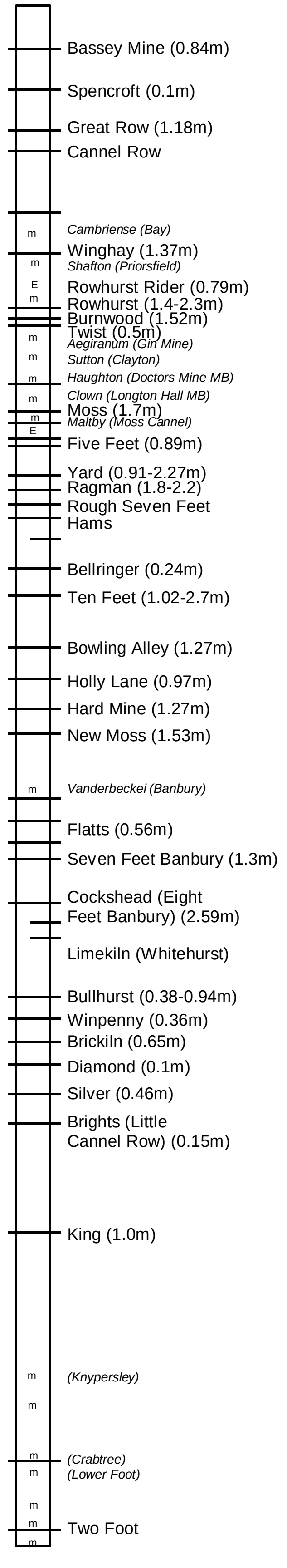


Figure 27. Stratigraphy of the main coal-bearing stratigraphic succession in the North Staffordshire Coalfield. Main seam names and thicknesses, where known, are labelled. m=marine band; E=Estheria band. Italicised text represent marine (or Estheria) band names.

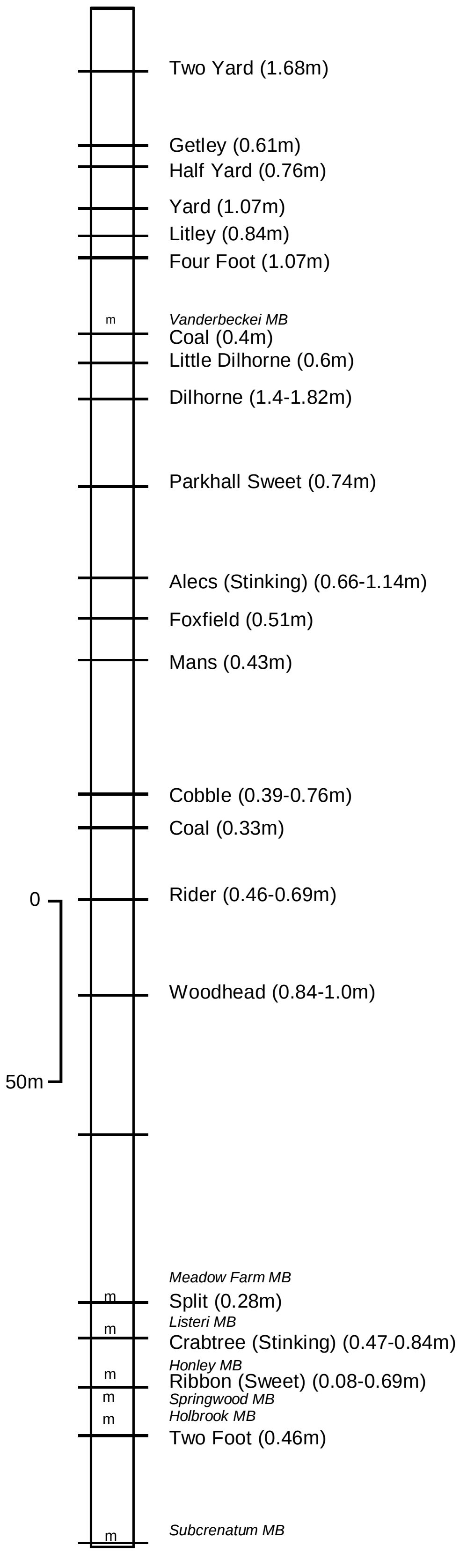


Figure 28. Stratigraphy of the main coal-bearing stratigraphic succession in the Cheadle Coalfield. Main seam names and thicknesses, where known, are labelled. m=marine band; E=Estheria band. Italicised text represent marine (or Estheria) band names.

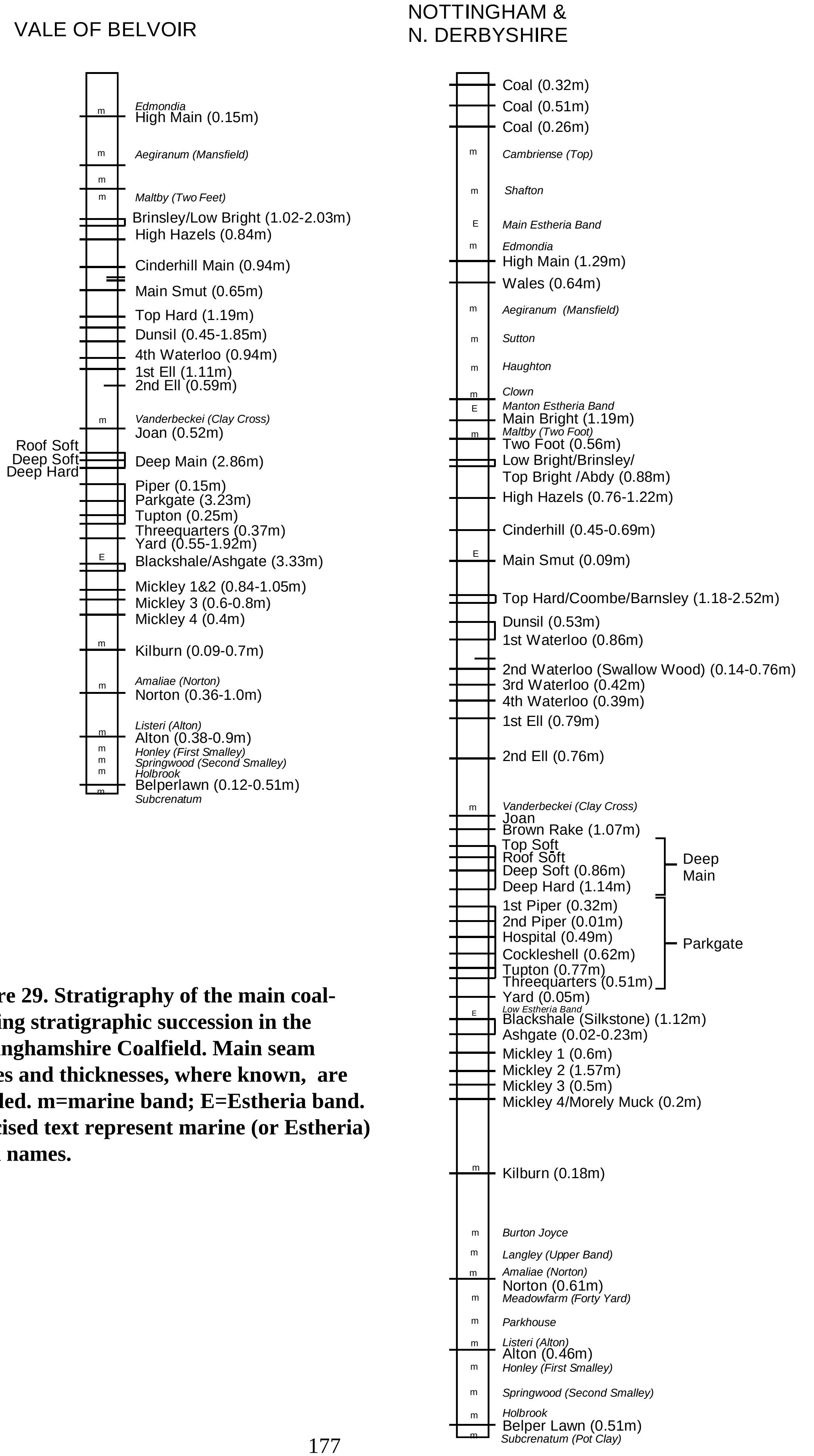


Figure 29. Stratigraphy of the main coal-bearing stratigraphic succession in the Nottinghamshire Coalfield. Main seam names and thicknesses, where known, are labelled. m=marine band; E=Estheria band. Italicised text represent marine (or Estheria) band names.

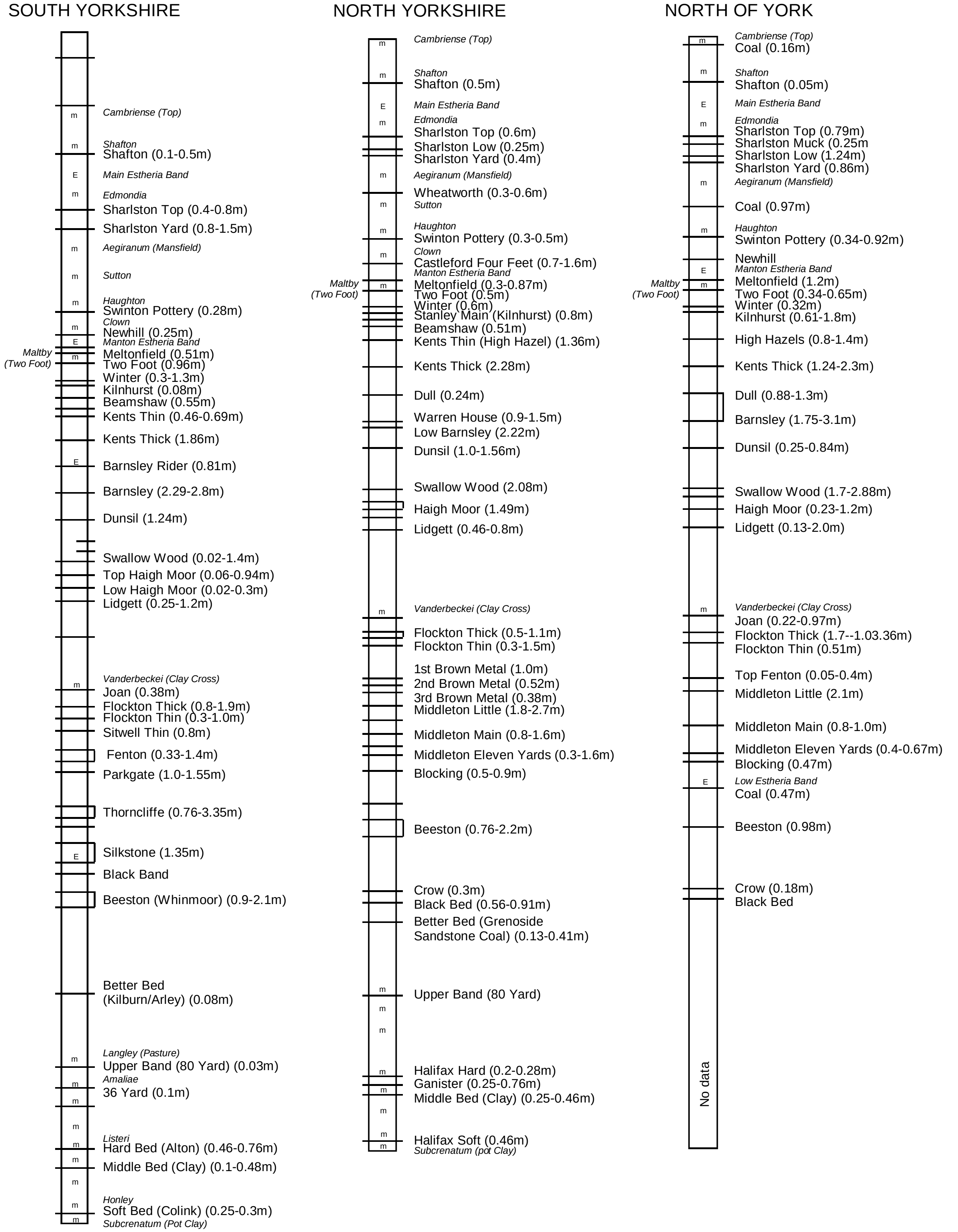


Figure 30. Stratigraphy of the main coal-bearing stratigraphic succession in the South Yorkshire Coalfield. Main seam names and thicknesses, where known, are labelled. m=marine band; E=Estheria band. Italicised text represent marine (or Estheria) band names.

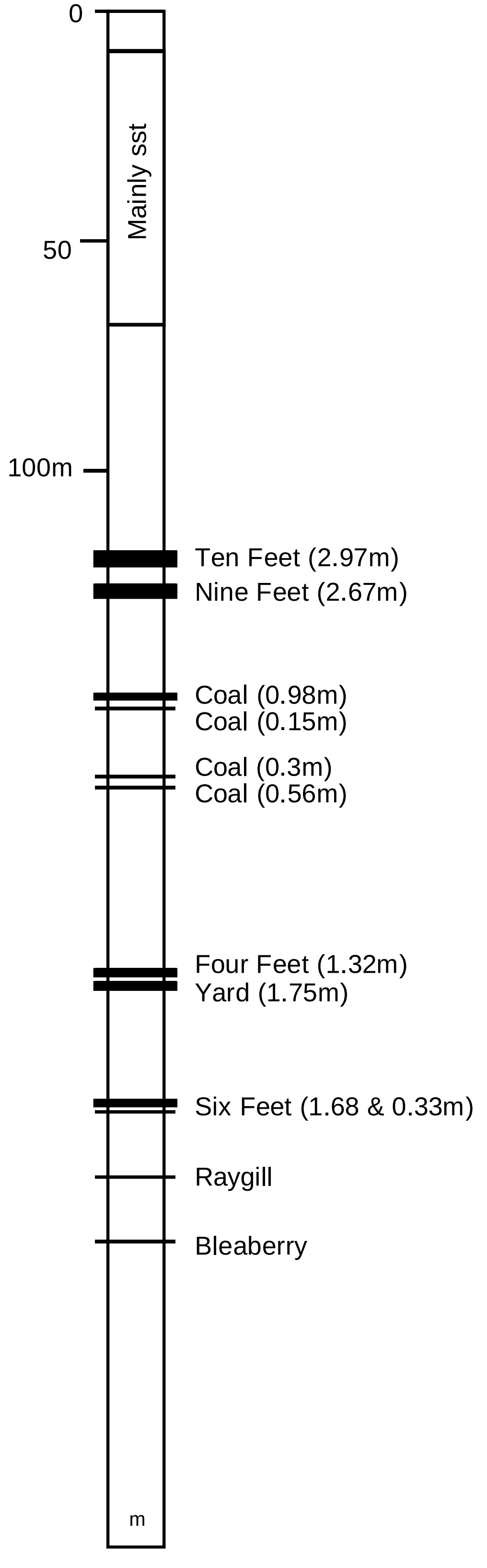


Figure 31. Stratigraphy of the main coal-bearing stratigraphic succession in the Ingleton Coalfield. Main seam names and thicknesses, where known, are labelled. m=marine band; E=Estheria band. Italicised text represent marine (or Estheria) band names.

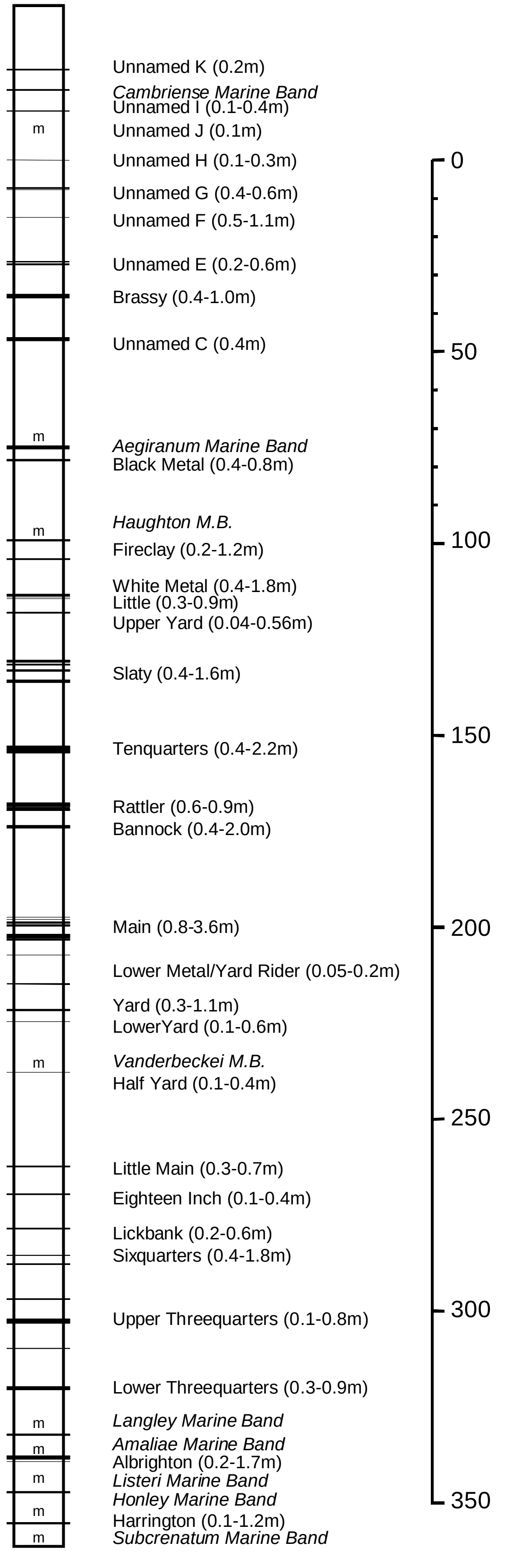


Figure 32. Stratigraphy of the main coal-bearing stratigraphic succession in the West Cumbrian Coalfield. Main seam names and thicknesses, where known, are labelled. m=marine band; E=Estheria band. Italicised text represent marine (or Estheria) band names.

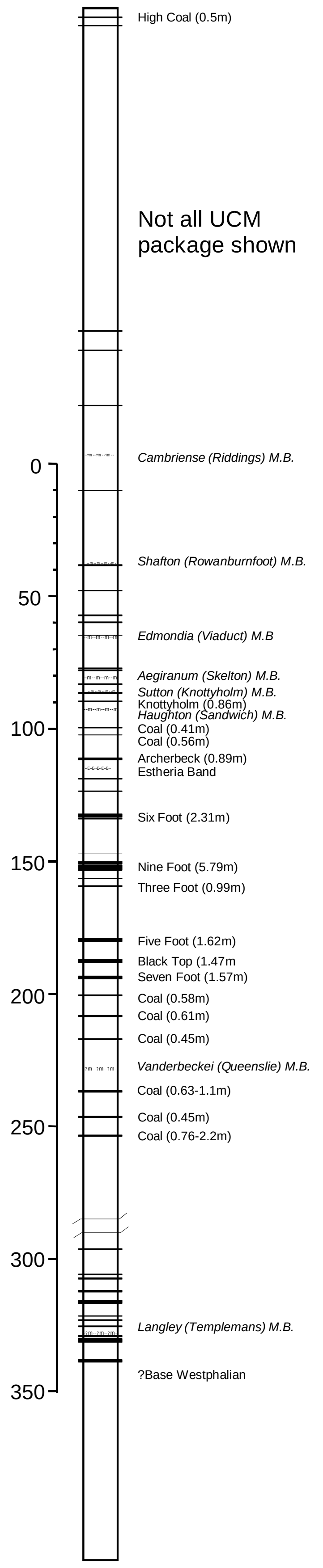


Figure 33. Stratigraphy of the main coal-bearing stratigraphic succession in the Canonbie Coalfield. Main seam names and thicknesses, where known, are labelled. m=marine band; E=Estheria band. Italicised text represent marine (or Estheria) band names.

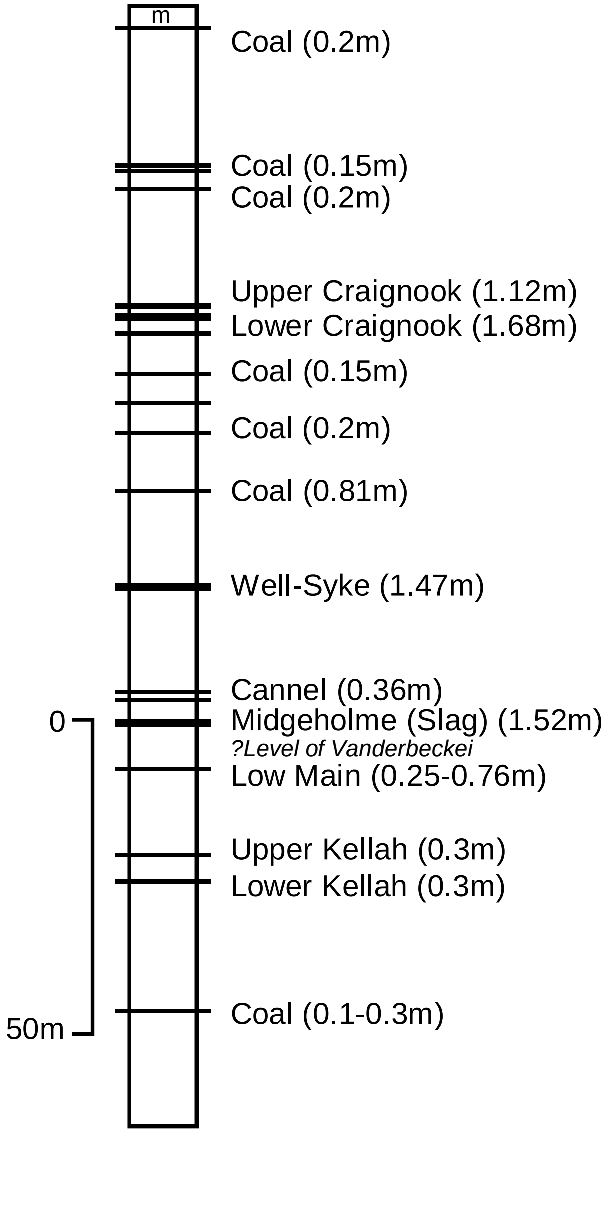


Figure 34. Stratigraphy of the main coal-bearing stratigraphic succession in the Midgeholme Coalfield. Main seam names and thicknesses, where known, are labelled. m=marine band; E=Estheria band. Italicised text represent marine (or Estheria) band names.

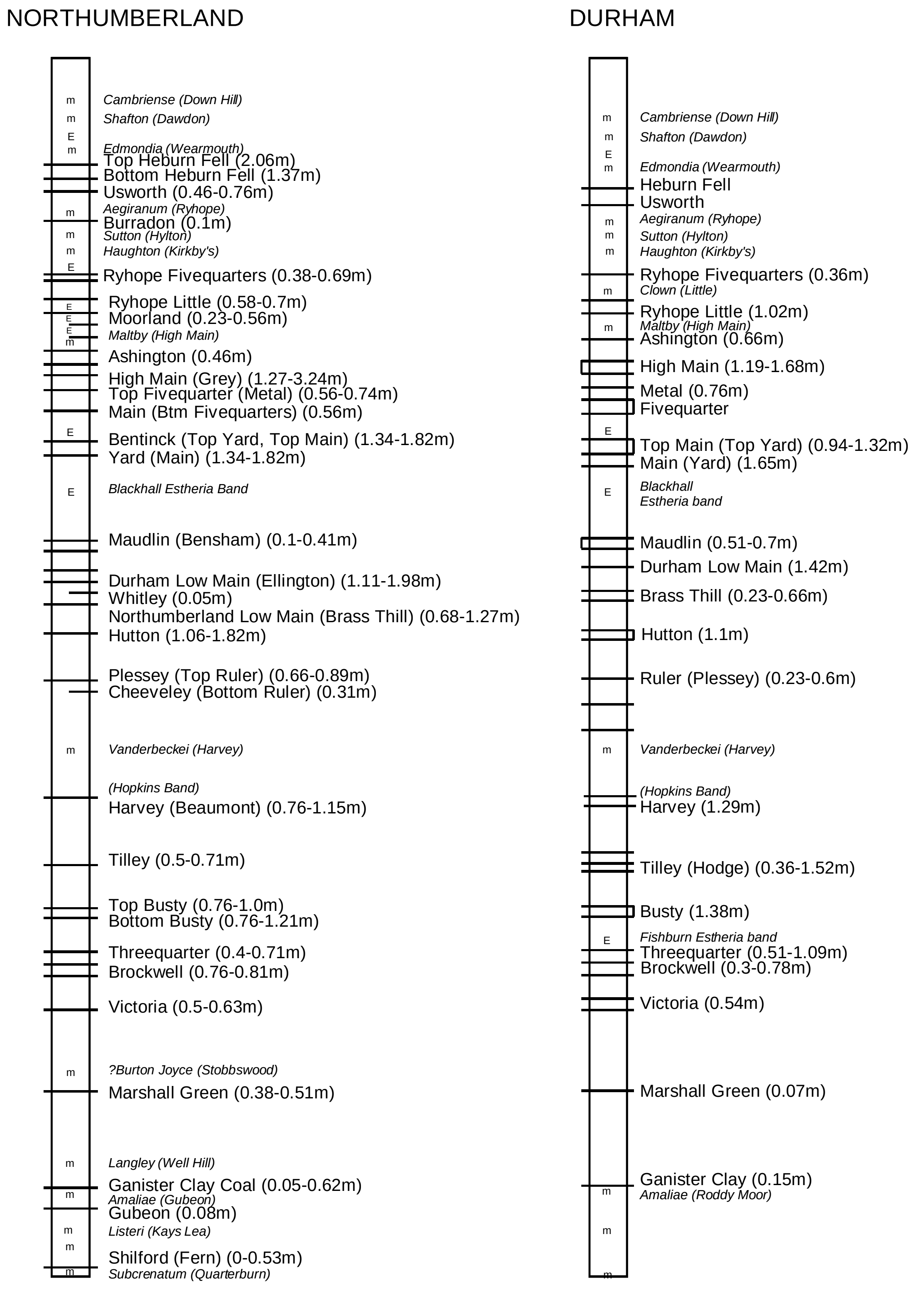


Figure 35. Stratigraphy of the main coal-bearing stratigraphic succession in the Northumberland-Durham Coalfield. Main seam names and thicknesses, where known, are labelled. m=marine band; E=Estheria band. Italicised text represent marine (or Estheria) band names.

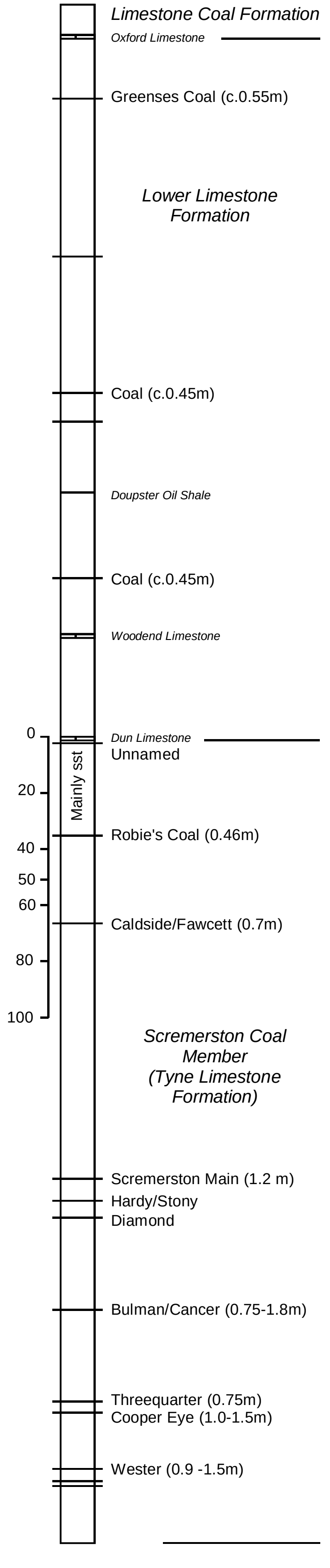


Figure 36. Stratigraphy of the main coal-bearing stratigraphic succession in the Scremerston Coalfield. Main seam names and thicknesses, where known, are labelled. m=marine band; E=Estheria band. Italicised text represent marine (or Estheria) band names.

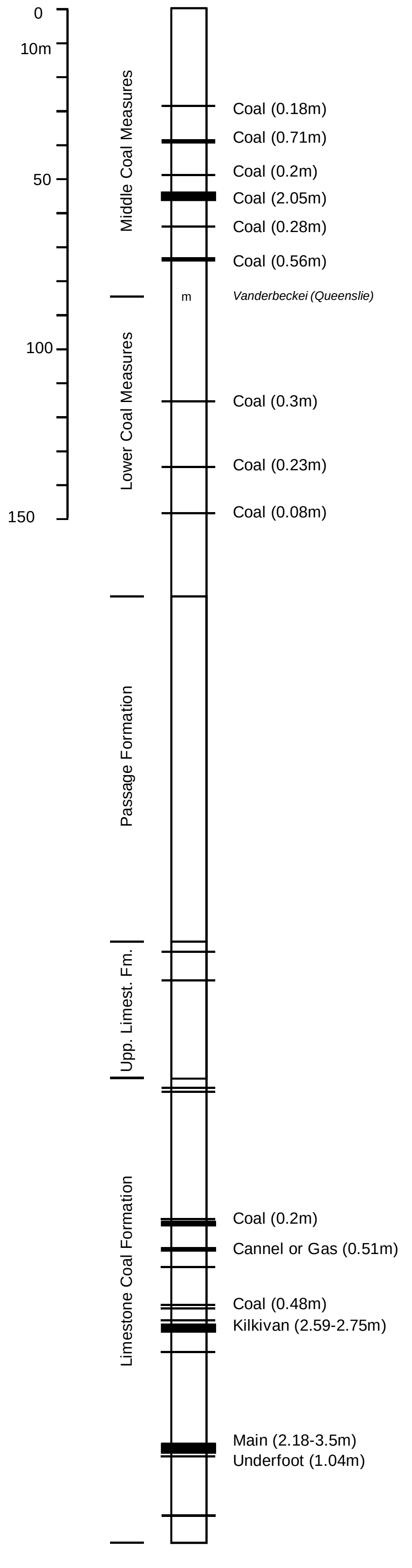


Figure 37. Stratigraphy of the main coal-bearing stratigraphic succession in the Machrihanish Coalfield. Main seam names and thicknesses, where known, are labelled. m=marine band; E=Estheria band. Italicised text represent marine (or Estheria) band names.

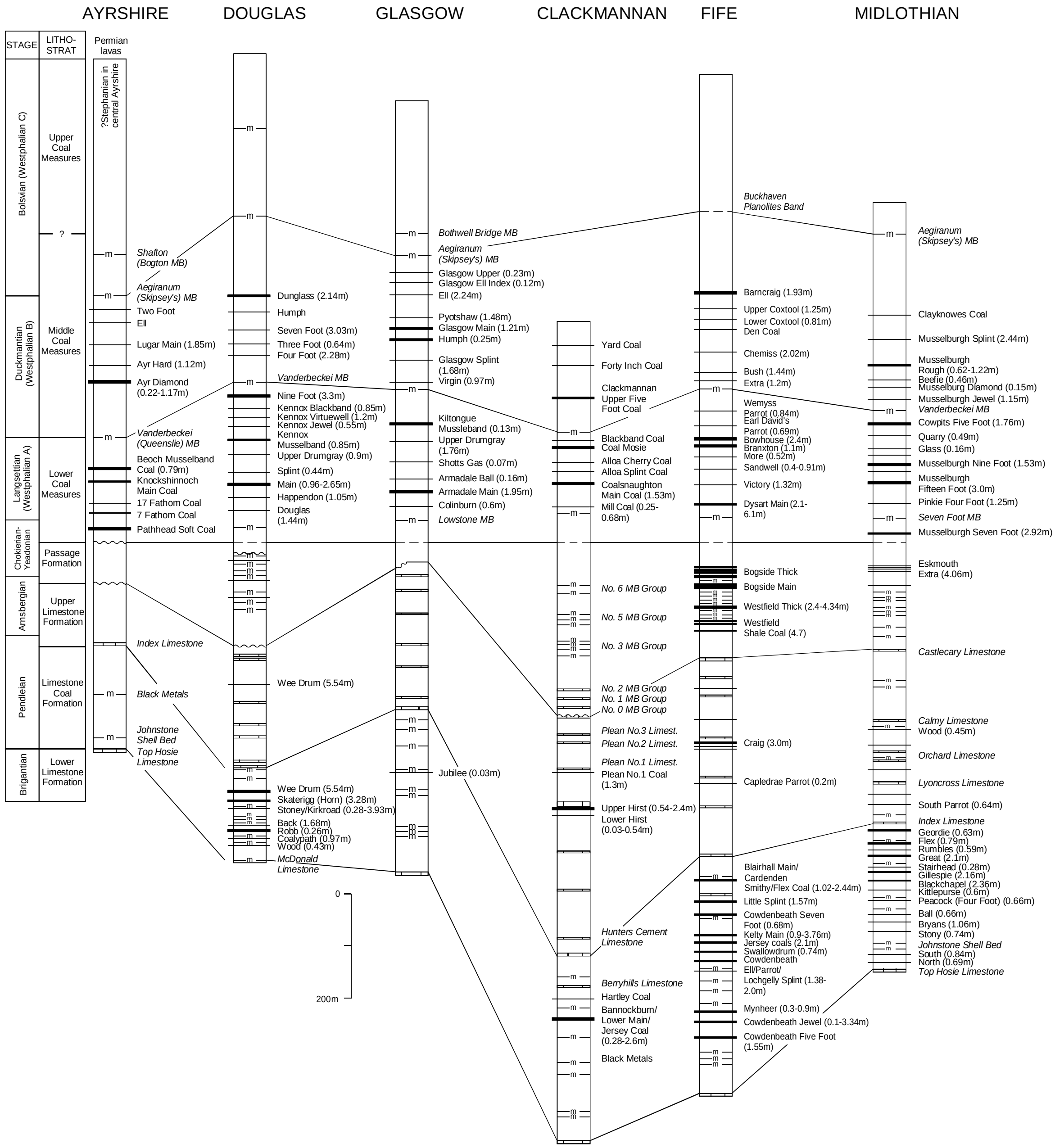


Figure 38. Stratigraphy of the main coal-bearing stratigraphic successions in the Midland Valley of Scotland. Main seam names and thicknesses, where known, are labelled. m=marine band; E=Estheria band. Italicised text represent marine (or Estheria) band names.

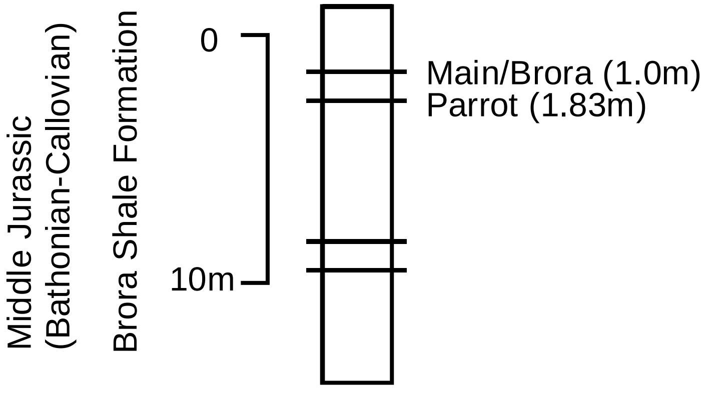
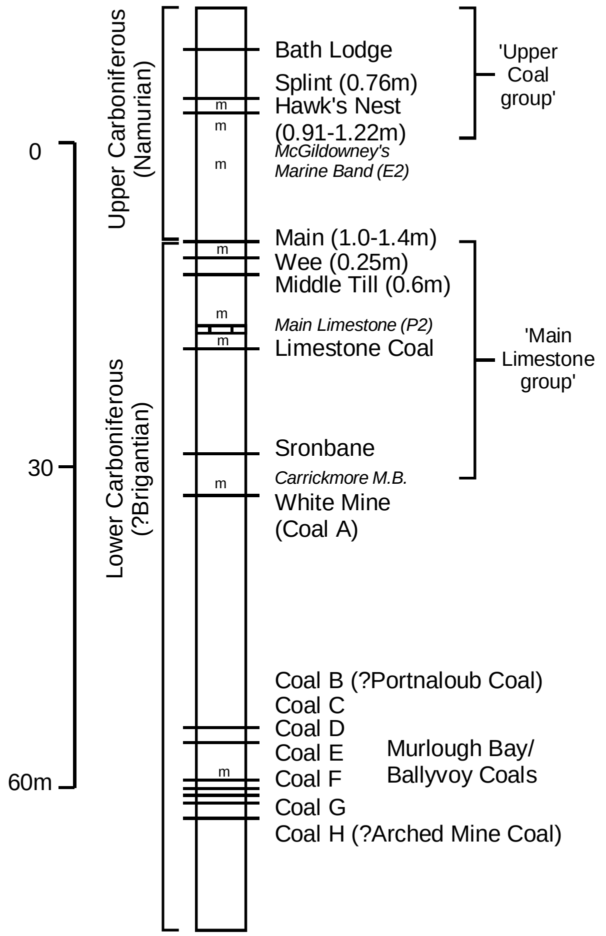


Figure 39. Stratigraphy of the main coal-bearing stratigraphic succession in the Brora Coalfield. Main seam names and thicknesses, where known, are labelled.



Redrawn from Wilson & Robbie (1966)

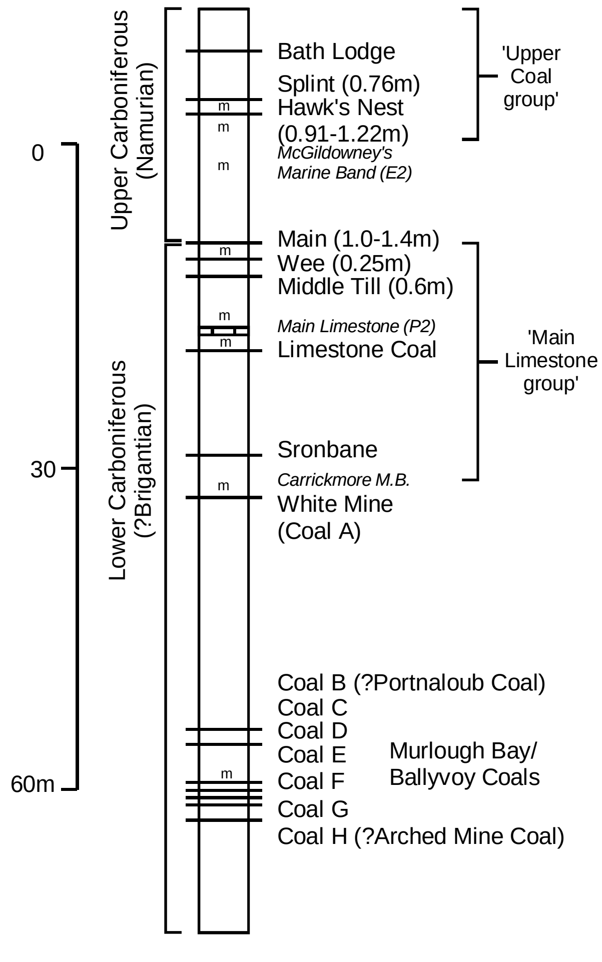


Figure 40. Stratigraphy of the main coal-bearing stratigraphic succession in the Ballycastle Coalfield, Northern Ireland. Main seam names and thicknesses, where known, are labelled. m=marine band; E=Estheria band. Italicised text represent marine (or Estheria) band names.

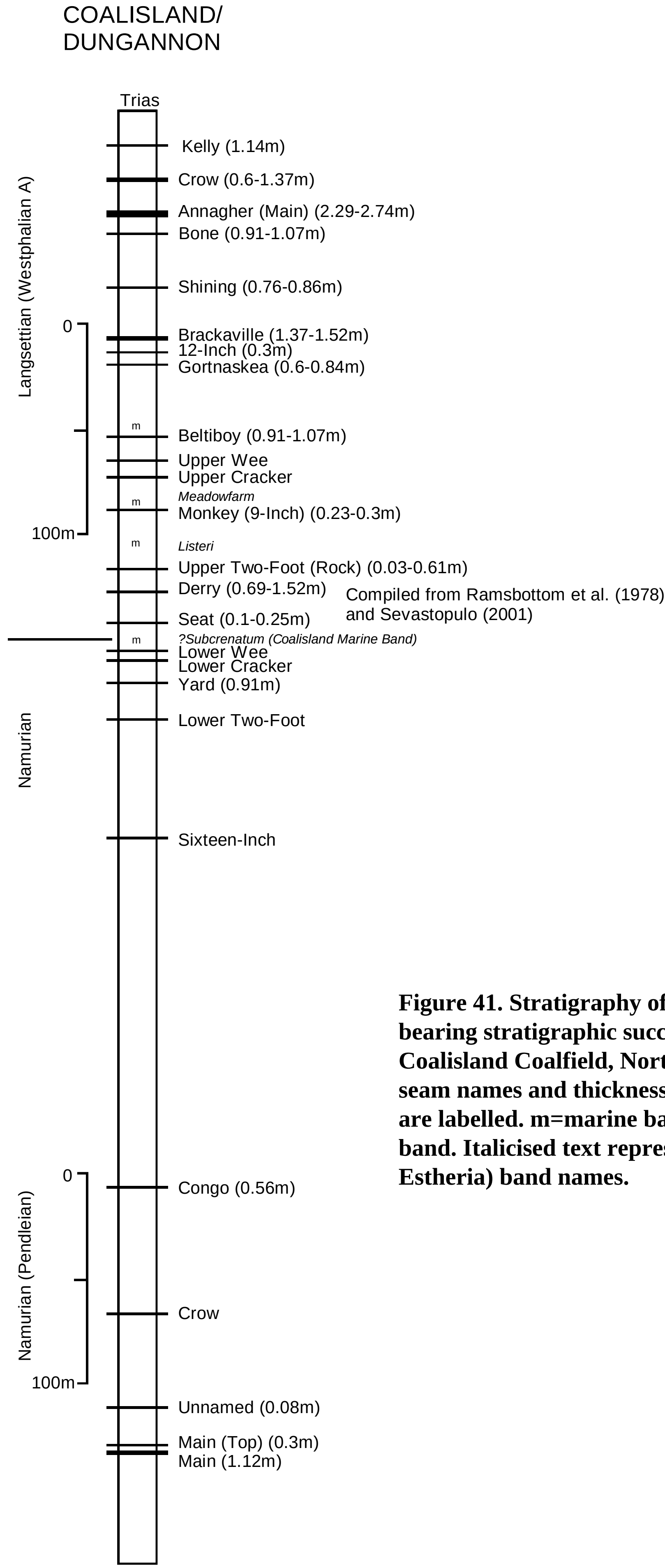


Figure 41. Stratigraphy of the main coal-bearing stratigraphic succession in the Coalisland Coalfield, Northern Ireland. Main seam names and thicknesses, where known, are labelled. m=marine band; E=Estheria band. Italicised text represent marine (or Estheria) band names.

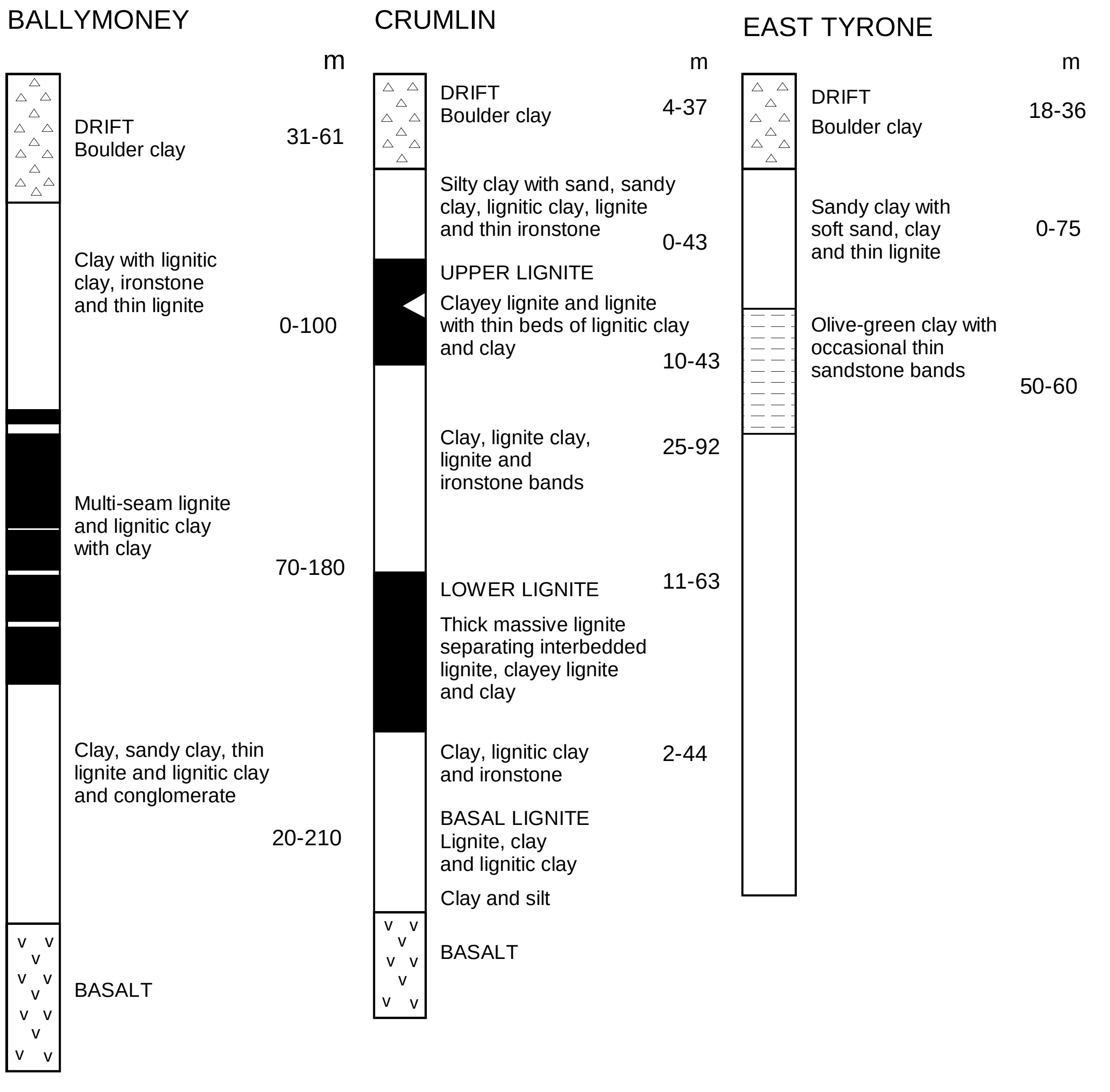


Figure 42. Typical successions within the Oligocene Lough Neagh Clays, Lough Neagh area, Northern Ireland (redrawn from Legg 1992).

1 APPENDIX 1: PDF DOCUMENT

As part of the deliverables for this project, an Adobe Acrobat pdf document was produced. This represents a digital version of all the 1:100,000 scale coal resource maps and the 1:1,750,000 and 1:600,000 montage map. This is a web-enabled document; the requirements needed to run this document are MS Internet Explorer or Netscape Web Browser. The pdf files can only be viewed using Adobe PDF Reader (v.6.0 or later is recommended), which is available as a free download from http://www.adobe.com/products/acrobat/. It is recommended that the file is run directly from CD-Rom as it will automatically run when inserted into a PC.

All text within the document is searchable using the Find command. For example "Jack Tar Pit" can be found on Maps 16a and 16b and Exploration Licence "EXL215" can be found on Map 12b.

MAPS

MINING TECHNOLOGIES

1a. Bovey Tracey
2a. Kent
3a. Western South Wales
4a. South Wales
5a. Forest of Dean, Newent and Bristol-Somerset
6a. Oxfordshire and Berkshire
7a. South Staffordshire, Warwickshire, Leicestershire, South Derbyshire and Shropshire
8a. Anglesey
9a. North Wales
10a. North Midlands
11a. Nottinghamshire
12a. South Yorkshire
13a. Ingleton
14a. Cumbria-Canonbie
15a. North East England (South)
16a. North East England (North)
17a. Machrihanish
18a. West Scotland
19a. Central and East Scotland
20a. Brora
21a. Northern Ireland

NEW TECHNOLOGIES

1b. Bovey Tracey
2b. Kent
3b. Western South Wales
4b. South Wales
5b. Forest of Dean, Newent and Bristol-Somerset
6b. Oxfordshire and Berkshire
7b. South Staffordshire, Warwickshire, Leicestershire, South Derbyshire and Shropshire
8b. Anglesey
9b. North Wales
10b. North Midlands
11b. Nottinghamshire
12b. South Yorkshire
13b. Ingleton
14b. Cumbria-Canonbie
15b. North East England (South)
16b. North East England (North)
17b. Machrihanish
18b. West Scotland
19b. Central and East Scotland
20b. Brora
21b. Northern Ireland

2 APPENDIX 2. TABLE A1: METADATA FOR BOREHOLES USED IN STUDY

Quarter Sheet (QS) and QS Number refer to BGS registered number for each borehole. # - Boreholes not registered in BGS collection. * - No data).

BOREHOLE NAME	QUARTER SHEET (QS)	QS NUMBER	BNG EASTING	BNG NORTHING	SURFACE ELEVATION (m)	TOTAL DEPTH (TD) metres
A1/10 TURF NEST	SJ69NE	4	368832	398234	18	548.82
A1/12 PEEL GREEN	SJ79NE	29	375407	398565	20.7	878.86
A1/2 PRESTWICH	SD80SW	7	380240	402850	39.3	847.55
A1/8 ASTLEY STATION	SJ79NW	10	370290	397259	24.05	1054
A1/9 MANOR FARM	SJ79NW	8	372121	397572	0.25	1104.42
A2/26 BLACK FIELD OFF MOSS LANE	SD51SW	25	353555	410971	93.36	486
A2/31	SD51SW	10	353886	414501	64.13	660.81
A2/59 ROSE COTTAGE	SJ69NE	5	367000	395818	20.36	997.19
A2/66	SD40SE	48	347922	402476	55.56	280.41
A2/68	SD40SE	65	345643	400576	41.61	376.62
A3/16 ARBURY LANE	SJ69SW	32	361500	392670	*	1075
A5/5 DUDLESTON	SJ33NW		334150	337840	1.07	792.48
AB KETTLEBY	SK72SW	47	472628	322628	128.48	672.01
ABERAVON MARSHES (BURROWS) No.2 BH	SS78NE	60	275050	189590	*	274.32
ABERDONA WOOD BORE NO1/1979	NS99NE	124	295434	695280	99.8	423
ABERDONIA MAINS BORE	NS99SW	289	294356	694798	96.77	418
ABERNANT COLLIERY SOUTH SHAFT	SN70NW	11	270180	208210	164.59	820.22
ABERNANT No.9 SURFACE BH. 'NANT-Y-GWYN'	SN60NE		269442	207400	292.13	1032
ABERTILLERY NEW MINE	SO20NW	1	320500	205800	247.12	303.58
ACASTER AIRFIELD SURFACE BH1	SE54SE	12	458330	443125	8.79	642.09
ACASTER AIRFIELD SURFACE BH2	SE54SE	13	457120	442160	8.54	566.14
ACKLINGTON STATION	NU20SW		422100	601533	40.9	563.04
ACKTON HALL COLL.	SE42SW	32	442250	420470	51.82	652.98
ACKWORTH	SE41NW	15	444310	416810	26.94	823.57
ACRE EDGE	SK76NW	38	470818	366952	91.46	909.27
ACRESFORD 6	SK31SW	65	430960	313580	107.9	716.58
ACRESFORD 7	SK21SE	9	429600	312970	73.15	308.15
ADAMTON MAINS NO.1 BORE	NS32NE	12	238160	628920	48.17	310
ADDERLEY GREEN 8	SJ94SW	7	392099	344522	190.8	399.74
ADLINGTON A2/23	SD61SW	6	360617	413918	121.8	289.56
AIRTH (1980)	NS88NE	215	289357	687661	21.71	638

ALDERSEY	SJ74SE	34	379528	343668	142.45	834.3
ALDWARKE MAIN No.1 SHAFT	SK49NW	19	444400	395100	33.53	452.04
ALFRETON COLL.	#	#	441720	356330	105.46	238.84
ALKBOROUGH A	SE82SE	3	488345	422644	7.27	1999.00
ALKRINGTON NEW COLLIERY 1	SD80SE	48	386805	404281	97.5	387.71
ALL HALLOWS	SK73NE	12	477758	336940	31.96	659.66
ALMA COLL	SK46NW		441290	366120	140.21	384.66
ALREWAS 1	SK11SE	7	418636	314067	51.51	1168.29
ALVELEY 1	SO78NE	2	378170	286080	146.61	516.94
ANN PIT WALKER	NZ26SE	125	429210	564590	*	*
ANNESLEY COLLIERY	#	#	451773	353287	142.3	583.1
ANNESLEY PARK	SK55SW	17	451717	351105	124.01	425.35
ANSTRUTHER NO9 BORE	NO50SE	5	356530	703500	4.11	305
APLEY 1	TF17NW	2	510147	375105	18.72	*
APLEY BARN	SP31SW	3	434370	210660	*	1506
APLEYHEAD 1	SK67NE	13	465510	376310	43.99	*
APPERKNOWLE	SK37NE	181	438140	378600	*	*
APPROACH FARM	SE63NW	31	462834	438874	5.78	811.72
ARCHERBECK	NY47NW	14	341568	578152	*	1403
ARMTHORPE BH	SE60SW		462051	403678	15.24	659.8
ARNS BORE NO1/77	NS99SW	293	290890	690058	1.3	684
ARRAIL GRIFFIN COLLIERY, NO.5 PIT	SO20SW	7	321880	202840	188.06	324.3
ASH FARM 1	SP22SW	20	420870	224410	129.54	1313.69
ASH WOOD BH	SE41NW	39	442100	417424	55.79	432.2
ASHBURNHAM. NO.4 BOREHOLE	SN30SE		239060	203020	9.14	385.27
ASHERTON BH.1	NS41SW	140	243829	613882	190.3	537
ASHINGTON 20/65	NZ28NE	100	425790	589390	-34.28	271.88
ASHINGTON COLL CARL DOWNCAST	NZ28NE	31	426540	588060	35.3	317.85
ASHINGTON COLLIERY SURFACE BORE	NZ28NE	158	427060	589990	20.6	327.42
ASHLEY HOUSE	SK21NE	58	425130	318110	63.23	622.25
ASHOW	SP37SW	100	430531	271614	85.85	1244
ASHTON MOSS COLLIERY, SNIPE PIT	SJ99NW	9	391937	397942	100.6	930.86
ASKERN 1	SE51NE	1	456507	415008	7.42	*
ASKERN COLL.1 SHAFT	#	#	455800	413800	24.38	749
ASKHAM 1	SK77SW	42	474287	374717	37.2	*
ASTLEY GREEN 1 PIT	SJ79NW	1	370465	399920	*	809.85
ASTLEY NEW PIT, DUKINFIELD	SJ99NW	16	393911	397184	*	631.39
ASTLEY RAYNERS	SJ79NW	3	370230	398624	*	522.27
ASTON TIRROLD	SU58NE	42	455790	187220	54	740.93
AUCHENTYRE BH	NS98SW	178	290056	684680	6.41	626
AUCHINBAIRD BORE 1980	NS89NE	102	289642	695022	40.17	619
AUCHINBEE NO.1 BORE	NS77NW	184	273225	675665	82	546
AUCHINLECK MAINS BORE	NS52SW	65	250500	623044	119.7	950

AVENUE COLL.	SK36NE		432940	367930	91.44	233.17
AVERHAM PARK G1	SK75NW	11	474500	356298	48	805.89
AVONMOUTH 2 (SEVERN FARM)	ST58SW	2	355440	176310	6.78	112.01
AXHOLME 3	SE70SE	8	478685	404435	22.3774	*
AYLESFORD COVERT BH	SK62SE	25	467553	320791	128.07	583.87
BA/23/2	SD73SE	39	378480	433930	108.2	315.16
BABWORTH	SK68SE	27	468950	380270	32.3	1067.1
BACK LANE PLUNGAR	SK73SE	65	476255	332789	54.4	730.66
BACKWORTH MAUDE PIT FROM SUFACE TO BRASSTHILL 'K' AND STRATA IN THE 'A' PIT.	NZ37SW	48	430369	571927	58.52	256.34
BACKWORTHCOLLIERY BELOW BRASS THILL 'K'	NZ37SW	49	430376	571897	-197.82	419.25
BADSWORTH COMMON	SE41NW	1	444900	415200	45.68	830.88
BAGGERIDGE 2 WOMBOURNE	SJ89SE	3	387250	294060	85.34	1021.66
BAGGERIDGE 5 PENN	SO89NE	6	389250	296540	132.01	776.33
BALCORMO NO1 BORE	NO50SW	39	350836	704084	32.98	347
BALCORMO WOOD NO2 BORE	NO40NW	57	341320	705750	297.5	309
BALFOUR MAINS 1	NT39NW	10	333072	699891	22.86	1382
BALGRUMMO NO.1 BORE	NO30SE	5	337190	703170	78	235
BALGRUMMO NO.1 BORE(NORTH)	NO30SE	6	337585	703800	68	331
BALGRUMMO NO.2 BORE	NO30SE	4	337090	703325	94	434
BALORNOCK DIAMOND	NS66NW	32	262340	668750	*	357
BANGLEY BOREHOLE	SJ91SW	41	394440	313980	101.5	932.94
BANK END	SK79NW	2a	470630	399717	0.81	1063.75
BANK END MARYPORT	NY03NE	3	305130	538460	*	807.11
BANK TOP PIT 1	SD70NE	19	379258	409177	*	438.3
BARHAUGH	NY75SW	4	371800	552500	*	*
BARKESTONE WOOD	SK73SE	57	479316	333078	62.8	664.07
BARKSTONE BRIDGE	SK73SE	59	477316	334986	46.32	722.72
BARLBOROUGH 2	SK47NE	3	449029	377619	127	582.78
BARMULLOCH FARM	NS66NW	39	262880	668130	*	292
BARN HOUSE	SK47NW	142	444590	376750	55.5	282.42
BARNARD GATE	SP41SW	45	441688	210205	68.08	287.12
BARNBOROUGH No.5 SHAFT	SE40SE	14	447699	403200	38.34	706.68
BARNBY MOOR	SK68SE	16	466304	383643	18.12	1040.92
BARNHILL BORE (1939-40) NO.3	NS41NW	133	244380	615010	156	356
BARNSDALE	SE51SW	2	451720	413860	66.57	803.38
BARNSLEE 2	NO30SW	98	330790	701855	57.91	238
BARNSOLE	TR25NE	122	628240	156780	18.9	836
BARONY PIT SHAFT	NS52SW	4	252820	621730	130	627
BARREL HILL	SK76NE	70	478437	365927	14.05	865.5
BARRINGTON COLLIERY MOLLY PIT	NZ28SE	29	426500	583660	26.31	387.8
BARROW COLL.	SE30SE	9	435864	402627	75.75	430.35
BARROWS GREEN	SJ58NW	72	353219	387928	28.77	933.98

BARTON 1	SJ45SW	22	343573	354095	20.09	1032.07
BARTON 1	SE76SW	22	472199	464674	39.5	*
BARTON 2	SJ45SW	22	343573	354095	20.09	1032.07
BASSINGFIELD	SK63NW	45	461228	337224	28.27	501.68
BASSINGHAM FEN	SK95NW	16	493190	358560	7	863.6
BATES PIT NO3 NEW SHAFT	NZ38SW	24	430490	582250	4.9	301.59
BATH FARM BOGSIDE NO4 BORE	NS98NE	117	295275	689563	65.01	418
BATHLEY HILL	SK75NE	151	476599	359877	49.94	587.19
BATLEY WEST END COLLIERY	SE22NW	492	424557	425551	82	273.41
BATSFORD LOWER LEMINGTON	SP23SW	3	421500	234700	115.8	518.31
BAYTON	SO67SE	14	369800	273040	*	100
BEACON	SJ92SW	97	394321	324771	93.88	989.61
BECKERING 1	TF18SW	13	510396	380252	32	*
BECKHALL	NY37NW	2	333924	575733	89.34	420
BECKINGHAM 1	SK79SE	4	479214	390365	4.7244	*
BECKLEES	NY37SE	3	335166	571578	35.25	1370
BEDLAY (MOLLINBURN) NO 2 BORE	NS77SW	43	271385	670645	85	557
BEDLINGTON 'D' COLLIERY 5	NZ28SW	62	424820	580960	-68	202.1
BEDWELLTY No.1 PIT	SO10NE	2	315452	206290	272.19	245
BEECHDALE ROAD	SK54SW	17	453612	341130	47.95	643.13
BELLAMOUR	SK02SW	1	404650	320450	72.18	386.66
BELLSDYKE NO.1/78	NS98SW	176	290953	684891	5.67	612
BELTON 1	SE70NE	4	477730	408450	4.57	*
BELVOIR 1	SK83SW	107	480924	333979	63.21	*
BENTINCK COLL.	SK45SE		448770	354970	115.82	461.95
BENTLEY COLL. SHAFT No.2.	#	#	457000	407500	6.4	811.9
BERSHAM COLL 1 PIT	SJ34NW	2	331460	348260	*	396.11
BERSHAM COLL 2 PIT	SJ34NW	1	331470	348180	*	391.31
BESTWOOD COLL.	#	#	455669	347486	69.49	378.28
BETTERAS HILL	#	#	449345	429110	34.37	311
BETTESHANGER 1 DB	TR35SW	1	633910	152950	-551.48	78.33
BETTESHANGER 14 DB	TR35SW	10	633670	152920	-640.54	93.37
BETTESHANGER 2 & 3 UBH	TR35SW	2	631980	154880	-550.16	231.22
BETWS SURFACE BH. NO.12 ('HAFOD')	SN60NE	11	267873	209348	225.52	820.18
BETWS SURFACE BH. NO.13 ('HENRHYD')	SN61SE	53	267863	210494	298.9	644.74
BEVERCOTES PARK	SK67SE		469306	371727	27.02	870.37
BEVERCOTES VILLAGE	SK77SW	37	470290	371838	40.4	*
BGS GRASSYARDS FARM 1150 YDS NORTH OF MOSCOW	NS44SE	52	248670	641380	141	*
BH 6	NY03SW	38	301330	530950	35.97	239.88
BH AT DEWHURSTS MILL BIRSTALL YORKS	SE22NW	1	422610	425388	*	365.76
BH AT THE WORKS OF YORKSHIRE ARTIFICIAL SILK CO BR	SE12SE	4	415056	422619	*	224.03
BH NO 2 MOSS BAY	NX92NE	15	299070	527640	*	262.43

BH NO. 2 MOOR ROW	NX91SE	123	299982	514230	73	428
BH NO. 3	NY02NW	4	301450	527650	16.15	236.71
BH NO.1 BRAYTON	NY14SE	1	316460	544340	*	384.81
BH NO.2 BRAYTON	NY14SE	2	317190	544530	*	574.55
BICKRAM NO1 BORE, OAKLEY	NT09SW	294	300660	691260	93	590
BIDSTON	SJ29SE	2	328340	390880	*	*
BILLINGLEY LANE BH	SE40NW	121	443000	405647	37.3	209.75
BILLINGSLEY	SO78SW	14	371570	284280	114.91	117.96
BILSTHORPE COLLIERY No.1 SHAFT	SK66SE	103	465000	361000	74.8	746.97
BINGHAM 2	SK73NW	1	471691	339557	24.16	*
BIRCH HILL	SK46NE		449050	367840	152.1	407.88
BIRCH TREE FARM	SP38SW	161	431016	282882	134.89	862.67
BIRCHWOOD	SJ69SW	1399	364382	390996	13.035	1528
BIRDSTON NO.2 BORE	NS67NE	19	265530	675810	45	524
BIRKS OPENCAST BH M/15	NY01NW		302195	515999	*	*
BISCATHORPE 1	TF28SW	11	523050	383714	87.48	*
BISHOP SUTTON NEW PIT	ST55NE	2	358280	159240	69.4	225.5
BISHOP WOOD 2	SE53SE	22	455445	434982	7.62	355.28
BISHOP WOOD 3	SE53SE	23	456036	433630	7.19	318.63
BISHOP WOOD 6	SE53SE	26	456355	433757	7.12	290.63
BISHOP WOOD BH (505)	SE53SE	18	455179	433523	7.52	407.97
BISHOPBRIGGS TOWN CENTRE BH.01R BISHOPBRIGGS	NS67SW	212	260400	671000	0.5	*
BLACK BANK SHAFT BEDWORTH	SP38NE	9	435756	286093	102.4	206
BLACK BROOK BRIDGE	SJ34NW	44	331850	345730	*	334.67
BLACKHALL, BATTERSLEY FARM BOREHOLE	NZ43NW	43	444550	536999	88.7	338.23
BLACKLAKE	SJ93NW	1	393430	339300	247.45	1087.83
BLACO	SK68NE	35	469160	387585	15.37	1082.02
BLACON	SJ36NE	22	336825	367728	8.42	856.95
BLAIR MAINS NO 2 BORE	NS98NE	4	297120	686038	30.02	908
BLAIRHALL NO1 DIAMOND BORE	NT08NW	92	300875	688640	64	651
BLAIRMULLOCH FARM, BGS BORE	NS52NE	21	256050	628200	171	212
BLAITHWAITE 3	NY24SW	4	322242	543964	*	295.05
BLAKELEY HALL COLLIERY NO.1	SO98NE	42	399946	289508	1.5	286.46
BLAKELEY HALL COLLIERY NO.2	SO98NE	42	399916	289521	1.5	288.5
BLAKEMORE COLL	SO77SW	25	372400	272300	*	89.91
BLIDWORTH COLLIERY	SK55NE	6	459457	356564	120.7	670.38
BLINKEERIE BORE NO1	NS98NE	130	296721	689360	64.81	775
BLOODMIRE BORE	NS83SW	194	284060	631920	*	899
BLYTON 1	SK89NW	1	484345	395550	7.13	*
BOARDED BARN	SJ59SE	51	357197	393549	25.2	973.11
BOCKENDEN WARWICKS	SP27NE	50	428010	275250	90.52	1147
BOGRA	NY37NW	3	332864	575529	88.4	447
BOGSIDE 1	NS66NW	217	264320	668420	*	270

BOGSIDE (BATH FARM) NO3 BORE	NS99SE	117	295969	691005	39.92	428
BOLD COLLIERY SHAFT 1	SJ59SW	31	354830	393460	35.9	839.11
BOLD SH 3	SJ59SW	26	354860	393500	33.22	839.43
BOLSOVER COLL.	SK47SE		446080	371030	68.58	692.59
BORE 1/78, WESTRIGG	NS96NW	211	290131	666830	184.1	580
BORE AT GARTARRY TOLL	NS99SW	143	293132	691256	29	1342
BORE IN NELLIE PIT LOCHGELLY	NT19SE	27	318450	694740	88	202
BOREHOLE EAST OF BUTTERWICK IN A WOOD KNOWN AS BUTTERWICK BELT	NZ32NE	2	439909	529814	90.61	298.86
BORELAND BORE DYSART	NT39SW	44	330394	694222	62.5	1006
BOTANY BAY	SJ79NW	4	372710	398597	22.9	596.04
BOTHAMSALL 1	SK67SE	1	465860	373675	35.74	*
BOTTESFORD 3	SK73NE	2	478609	339191	28.04	*
BOURNE BROOK	SK11NW	13	413477	316246	63.57	583
BOWHILL BORE NO.12	NS41SW	114	243810	612310	300.01	580
BOWHILL COLLIERY NO3 SHAFT	NT29NW	332	321070	695630	90.22	818
BOWSEY WOOD	SJ74NE	9	376950	346430	91.44	931.47
BOWTREES BH.	NS98NW	204	291030	686078	5.22	613
BOX FARM No.1 BH	SN50SE		258190	201430	7.06	115.20
BRACKLEY COLLIERY A1/15	SD70NW	87	370216	405382	*	282.63
BRADES COLL. NO7	SO98NE	210	397750	289660	178	217.17
BRANCOTEGORSE COVERT	SJ92SE	6	395984	323055	89.48	879.25
BRANDFIELD FARM BH	SE50SW	48	453720	403567	32.54	472.24
BRAYTON DOMAIN COLLIERY 3	NY14NE	1	317140	545280	*	887.2
BREACH FARM	SK21NE	3	426640	318820	68.06	281.64
BRECK'S FARM	SK66NW	20	464378	366530	50.19	762.01
BREIGHTON AIRFIELD	SE73NW	8	472929	435257	5.13	1085.97
BREIGHTON SURF. BH. (LUND LANE)	SE73SW	10	470560	433046	5.3	1133
BRIARTHORN NO.1 SEABORE (NCB)	NT37NE	46	335426	675432	-9.9	250
BRIARTHORN NO.2 SEABORE (NCB)	NT37NE	47	335870	676801	-11.4	277
BRIARTHORN NO.3 SEABORE (NCB)	NT37NE	48	337403	678448	-12.8	412
BRICKKILN PLANTATION	SJ71SW	6	374692	313520	141.34	478.21
BRICKLAND	SJ92NW	33	393203	327023	112.97	1100.2
BRICKLAWN	SJ92SE	10	397664	323606	104.85	981.46
BRIGG 1	TA00NW	122	503777	406391	8.1	1933.4
BRIGG 2	TA00NW	123	503770	406390	8.16	1990
BRIND COMMON	SE73SE	2	475200	431294	4.64	993.96
BROACH ROAD BRANT BROUGHTON	SK95SW	7	492920	354550	10.5	993.96
BROADMEADOWS	NY37NE	15	337646	576265	80	791
BROCKET WOOD SURFACE BH	SE54SE	14	456709	444088	9.39	752.64
BROCKLEHILL FARM BH. 6	NS42SW	1	240214	624362	55	231
BROCKLEY	SK65SE	12	465939	354005	90.1	980.06
BRODSWORTH MAIN COLLIERY NO.1 SHAFT	SE50NW	5	452590	407711	37.26	772.88
BROOKFIELD	SJ34NW	52	332270	346500	*	376.91

BROOMFLEET 1	SE82NE	10	489324	427706	5.01	616.91
BROOMHILL MINE BH.88/K/1	NS41SW	9768	242886	613291	204.07	224
BROOMHILL MINE BH.88/K/5	NS41SW	9768	242540	613272	211.67	319
BROOMHILL MINE BH.88/K/6	NS41SW	9768	242407	613395	222.85	280
BROOMHILL MINE BH.88/K/7	NS41SW	9768	242689	613464	209.64	307
BROOMSTON	SK79NW	32	473240	397691	6.07	1099.3
BRORA BH.C	NC80SE	2	289116	903955	*	67.64
BRORA BH.F	NC80SE	8	289489	904159	*	54.86
BROUGHTON B-1	SE91SW	456	494627	410760	68.2	*
BROXTOWE PIT	SK54SW	37	452360	342930	80.77	234.21
BRUCEFIELD MAINS BORE	NS99SW	288	294394	691652	52.94	414
BRYMBO COLL. ENGINE,BYE PIT	SJ25SE	1310	329327	353494	*	211.4
BRYNKINALLT	SJ23NE	10	329930	338642	121.92	222.45
BULCOTE FARM	SK64SE	18	466293	344037	18.49	510.54
BULLCROFT COLL. No.1 SHAFT	#	#	454027	409698	10.67	626.62
BURGH LANDS, PRESTWICK BH.2	NS32NW	17	234580	626840	*	228
BURNLIP DIAMOND BORE	NS76NW	140	273385	667860	97	603
BURNSIDE DIAMOND BORE	NO30SE	7	336980	704150	83	331
BURNT HILL	SU57SE	76	457200	173800	118.1	1172
BURRADON HOUSE BOREHOLE	NZ27SE	19	427386	573127	63.61	399.06
BURTON COMMON 2	SE42NE	28	449862	427408	*	*
BURTON COMMON 3	SE42NE	28	449862	427408	*	*
BURTON JOYCE STATION FIELD	SK64SW	21	464520	343040	19	882.7
BURTONS SH	SJ25SE	6	327852	350850	*	291.08
BURTON-UPON-STATHER 1	SE81NE	2	487865	418829	64.16	*
BURTONWOOD	SJ59SE	22	355770	390200	19.39	843.08
BUSKEYFIELD LANE	SK57SE	15	456171	371988	57.17	802.84
BUTCHER'S BH.	SN61SW		264874	210453	235.4	416.66
BUTTERWICK 1	SE80NW	1	484210	405630	5.26	1700.00
BYRAM ASH	SE42NE	41	449862	427408	12.86	323.93
BYRAM PARK BH 1924	#	#	448620	426830	19.51	565.71
BYREBURN NO.1	NY37NE	9	339724	578598	76	229
BYREHILL LANDS NO. 4 BORE	NS24SE	52	229432	642524	12.5	238
CADDER NO 16 BORE	NS67SW	1	260035	673260	31.7	613
CADDER NO 5 (AUCHENGREE) BORE	NS66NE	5	265645	669730	79	456
CADLEY HILL	SK21NE	14	427750	318870	76.85	541.02
CADOXTON No.1 BH	SS79NE	31	275750	199000	N/A	620.34
CAIRNGILLAN BH.1	NS42NW	19	243246	625055	104	594
CAIRNY CROFT	NY66NE	2	366260	567032	158.5	412.17
CALDWELL 1	SK21NE	24	426000	317340	88.09	477.27
CALDWELL 2	SK21NE	25	425680	316720	86.87	481.58
CALDWELL 3	SK21NE	23	426600	317570	99.97	448.41
CALEDONIAN FARM	SK86NE	31	489513	366043	17.3	*

CALLOW 1	SK47SW		440860	370410	128	1132.95
CALLOW KNOWE BORE	NS83SW	204	283885	631175	193.2	1263
CAMERON BRIDGE DISTILLERY NO2	NO30SW	118	334580	700485	24	329
CAMERON NO1 BH	NT39NW	380	334566	699006	41.71	1472
CAMERON NO1 BH DIVERSION	NT39NW	380	334566	699006	41.71	1255
CANNOP 2	SO61SW	13	360780	212460	88.39	187.91
CARBANK	SK65NW	2	463969	355793	65.91	942.37
CARBERRY BORE DYSART NO1	NT29NE	49	328249	695574	82.3	625
CARBROOK MAINS NO1 BORE	NS88NW	52	284015	686195	18.65	517
CARDOWAN COLLIERY NO.3 SHAFT	NS66NE	106	266830	668230	*	658
CARDOWAN NO 1 BORE	NS66NE	65	268545	668130	79	566
CARDOWAN NO 2 BORE	NS66NE	66	267060	667520	82	551
CARDOWAN PIT NO2 SHAFT	NS66NE	67	266680	668320	*	626
CARDYKE PLANTATION NO.1	NS67SE	119	265150	670255	63	509
CARNOCK NO 1 BOREHOLE	NS88NE	2	286020	689000	15	533
CASTLE EDEN WEST PIT	NZ43NW	10	443710	538132	110.34	379.08
CASTLEHILL FARM	SK57NW	38	450116	378034	127.24	286.51
CASTLEHILL THORNHILL	NS43NW	148	240967	635058	45	501
CASTLESTEADS FARM NO 38 BORE	NT36NW	104	333860	669220	*	368
CATOR HOUSE SHAFT	NZ24NE		425857	545134	105.16	221.27
CATTLEMOSS NO1/64 BORE	NS99SE	127	299245	691742	84.8	528
CATTON HILL	SK21NW	1	421680	315370	77.65	664.92
CAUNTON 3	SK75NW	1	473275	359779	52.43	*
CAWLEY FARM	SJ69NE	26	366272	395281	23.65	1525.17
CAWOOD 1	SE53NE	6	456944	438376	8.03	822.96
CAWOOD 2	SE53NE	10	458211	436777	7.59	487.22
CAWOOD COMMON SURFACE BH	SE53NE	8	456394	435496	8.26	585.52
CAWOOD HAGG FARM SURFACE BH	SE53SE	19	456420	434450	6.61	352.71
CELLARDYKE HARBOUR TO THE PANS	NO50SE	13	357935	703835	2	382
CELYNEN NORTH COLLIERY, NORTH SHAFT	ST29NW	1	321271	197548	123.444	464.82
CHADKIRK PRINT WORKS	SJ98NW	14	393940	389570	*	229.82
CHAPELBURN 2	NY66SW	8	361220	564860	156.26	325.83
CHARLESTOWN SHORE SECTION	NT08SE	7	306500	683500	*	274
CHERRY WILLINGHAM 1	TF07SW	49	504165	373273	20.84	*
CHETWYND ASTON NEWPORT	SJ71NE	BJ	375900	318070	0.79	459.13
CHILDPIT LANE	SJ71NE	6	375608	315196	132.53	594.13
CHISLET COLLIERY UGB 33 & 34	TR26SW		622760	162920	-312.72	180.82
CHISLET COLLIERY UGB 35	TR25NW	3	621780	159720	-507.53	132.28
CHISLET COLLIERY UGB 38	TR26SW	11	620990	160670	-357.87	106.68
CHURCH GRESLEY MOIRA COLLIERIES	SK21NE	44	429210	318050	125.58	435.25
CHURTON	SJ45NE	27	345305	358667	18	1161
CINDERHILL COLL NO.2	SK54SW	31	453313	343659	11.96	201.95
CINDERHILL COLL. No.1	#	#	453320	343660	57.61	202.11

CLACKMANNAN NO1 BORE 1978	NS99SW	295	292154	691700	19.65	644
CLARA PIT GRIFFE COLLIERY	SP38NW	1	434812	288959	106.68	262.22
CLARBOROUGH 1	SK78SW	30	473842	383585	67.3	*
CLAVERLEY BOREHOLE	SO89SW	4	380350	291330	54.86	681.22
CLAY CROSS	SK36SE		439830	364380	102.72	576.99
CLAYPOLE 1	SK84NW	3	484505	349334	17.68	*
CLAYTON	SJ84SW	3	384870	343140	141	723.9
CLAYTONS HOUSE FARM	SJ59SE	17	358050	393070	13.79	1102.38
CLEETHORPES 1	TA30NW	51	530237	407090	4.5	*
CLIFFORDS WOOD	SJ83NW	8	384806	337449	183.55	1119.96
CLIFTON COLL.	#	#	456408	338140	25.42	274.76
CLIPSTON	SK63SW	21	463780	333140	57.91	641.6
CLIPSTONE No.1 SHAFT	SK56SE		459530	363290	88.39	600.67
CLOCKFACE SH 3	SJ59SW	5	353650	391610	49.93	752.68
CLUBS TOMB	NS88NE	216	288148	687421	9.41	511
CLYDE BRIDGE BORE MOTHERWELL	NS75NW	68	273795	656215	27	605
COACHGAP FARM	SK73SW	4	473463	334467	33.03	691.96
COCKBANK 2	SJ34NE	3	335700	345880	54.06	1236.27
CODSALL 1	SJ80NW	69	383300	305360	*	>940
CODSALL COLLIERY CRADLEY HEATH	SO98NE	214	395260	285760	116	211.23
COED TALON COLL. DEEP PIT	SJ25NE	18	327000	358800	*	219.66
COED TALON COLL. SOUTH LEVEL	SJ25NE	19	326970	358970	*	210.87
COEDELY BH.1, HENDREFORGAN BH	SS98NE	17	298690	187820	186.84	1036.47
COLDWELL FARM	SK36SE		437400	364240	152.4	205.03
COLLINGE	SJ47SW	23	341420	371110	14.8	1362.17
COLLINS GREEN	SJ59SE	4	355550	394250	39.62	521.45
COLSTON BASSETT NORTH 1	SK73SW	2	471000	333820	34.07	*
COLSTON BASSETT SOUTH 1	SK73SW	1	470390	331370	40.11	*
COMMON 1/80 BORE	NS52SE	327	257330	623210	187.3	650
COMMON FARM	SK54NW	65	450873	345793	112.4	562.8
COMMONSIDE	SK76NE	74	476782	366078	38.46	863.28
CONEYPARK COALFIELD NO73	NS77NE	21	277695	679400	67	223
CONEYPARK DIAMOND	NS77NE	81	277540	678880	45.62	548
CONINGSBY 1	TF25SW	18	524141	353567	7.19	*
CORKSCREW LANE	SJ34NW	50	331100	347160	*	279.2
CORRINGHAM 1	SK89SE	108	489310	39276	26.96	*
CORRINGHAM 7	SK89SE	113	489628	392997	22	*
CORSELET F.M. BORE	NS42SE	17	248473	621764	153.44	760
CORTONWOOD COLL. No.1	SE40SW	22	440662	401429	38.1	522.27
COTES PARK	SK45SW		442610	355010	138.99	269.9
COTGRAVE WOLDS HILL	SK63SW	17	464892	334335	59.84	862.58
COTON PARK GRANGE FM	SK21NE	70	427400	317430	76.79	226.16
COUSTON BALMUIR FARM BORE	NS97SW	99	294633	671441	114	546

COWGATE MINE BORE (1912)	NX91SE	120	299846	513784	*	288
CRAIGHEAD 1	NS86SW	330	282670	662120	246	914
CRAIGTON FARM NO1/77 BORE	NS98NW	196	292074	689095	5	537
CRANBERRY BORE	NY36NW	3	330724	569485	40.8	300
CRESWELL COLL. No.2 SHAFT	#	#	452290	373600	90.91	741.59
CRITCHLEY HOUSE A2/122	SJ69NW	41	362196	399343	82.1	390.39
CROCKLEY HILL	SE64NW	14	463094	446461	9.4	1051.5
CROFT PIT, PRESTON HOUSE	NX91NE	17	296557	515916	*	274.62
CRONTON A3/5	SJ48NE	4	348652	387425	20.53	885.19
CRONTON A3/8/1 (Windy Harbour)	SJ48NE	11	346000	389301	23.89	410.41
CROOKHOLM FARM	NY47NW	26	342452	576555	51.8	632
CROPWELL BISHOP 1	SK63NE	11	468778	338121	39.32	1119.53
CROPWELL BUTLER 1	SK63NE	12	468135	338695	63.65	980.55
CROPWELL BUTLER 2	SK63NE	73	467978	338234	59.13	*
CROSS HANDS No.1 BH	SN51SE	1	257397	210675	90.69	227.99
CROSS HILLS	SK56NW		450860	369470	124.66	784.87
CROWBRCHARD OR MOSSFIELD COLLIERY	SD40NE	16	348020	406860	*	489.38
CROWCROFTS	SJ94SW	13	390085	340010	142.72	659.58
CROWLE 1	SE71SE	7	477334	411923	5.2	1465.78
CROWN BREWERY DERBY STREET	SD70NW	29	371015	408198	*	207.42
CROXTON ABBEY	SK82NW	41	482841	327188	150.32	774.47
CRUCKMEDE SHAFT HANWOOD	SJ40NW	BJ	342070	309230	*	274.32
CRUCKMEOLE SH & BH	SJ40NW	5	342070	309230	82	274.32
CUCKNEY HOUSE	SK57SE	12	456259	370805	62.74	466.34
CUERDLEY MARSH 2	SJ58NW	9	354881	385638	*	502.92
CUERDLEY MARSH 3	SJ58NE	24	355310	386160	7.62	579.12
CUILHILL BORE	NS76NW	345	270127	665052	78.9	757
CULCHETH KENYON JUCNTION	SJ69NE	3	365216	396805	*	978.1
CULROSS BORE	NS98NE	2	296418	685958	20.62	849
CULROSS NO 2 BORE	NS98NE	5	298265	685869	4.29	686
CULROSS NO.3 BORE (OFFSHORE)	NS98SE	3	298441	684785	-3.41	998
CULROSS NO.4 BORE	NS98NE	169	296871	685425	4.1	866
CUNIGER ROCK SECTION	NO50SE	8	355200	702350	2	335
CUSWORTH BH	SE50SW	2	454168	404045	51.51	258.85
CUTNOOK	SJ79NW	73	371810	396285	26.79	1567.87
CUTTYFIELD	NS88SE	208	288881	684326	16.03	632
CWM SURFACE BOREHOLE No. 2	ST08NE	58	307912	188120	200.16	641.69
CWMGWILI No.4 BH	SN50NE	133	258426	209662	111.9	359.66
CWMTILLERY COLLIERY, NO.1 PIT	SO20NW	4	321650	205860	279.2	256.11
CYNHEIDRE 2/2	SN40NE		248072	206158	259.08	796.75
CYNHEIDRE 2/6 TREFANAU UCHAF	SN40SE		249969	203910	163.32	947.42
CYNHEIDRE 3/1	SN50NW	7	250173	207342	158.55	889.1
DAIRY PIT AT HAIGH	SD50NE	22	359700	407690	*	206.45

DALGINCH 8 HAND DIAMOND	NO30SW	84	331008	701405	54.47	221
DALHARCO NO. 1 DIAMOND BORE	NS41SW	95	242671	611483	253.5	396
DALMACAW FARM NO.2 BORE	NS41NW	140	243990	615140	147.07	254
DALMELLINGTON 237	NS40NE	249	248040	606150	187.79	988
DALMELLINGTON BH.211	NS41NE	52	245373	615326	-67.79	245
DALMELLINGTON BH.231	NS41NE	6	245420	618478	107.2	288
DANES	SK68NE	33	467769	385781	12.9	1054.42
DANS ROAD	SJ58NW	68	353451	386782	22.89	1144.83
DARDANELLES	SJ74SE	30	379832	344144	172.28	740
DARFIELD MAIN COLL. No. 3 SHAFT	SE40SW	47B	440100	403900	32.16	573.82
DARLTON	SK77SE		475750	373225	24.38	1070.47
DARNLEY NO2 BORE	NS55NW	62	252780	658750	31	304
DARRINGTON 1	SE41NE	20	446330	419380	30.48	656.06
DAW MILL ARLEY	SP28NE	5	425780	289820	*	565.2
DAWDON COLLIERY D8 BOREHOLE	NZ45SE		449692	552568	0	426.72
DAYWALL SH 2 & BH 1	SJ23SE	3	329490	334690	112.78	249.94
DEAF HILL BH NO 4	NZ43NW	49	440154	535331	*	317.6
DEAF HILL COLLIERY	NZ43NW	35	440164	535337	136.75	317.6
DEAN 7	NY02SE	152	307090	524730	110	329.48
DEE ESTUARY 1	SJ27NW	4	323370	378460	*	208.63
DEE ESTUARY 12	SJ27SE	13	327844	374805	4.09	247.49
DEEP GILL ST BEES	NX91SE	208	297655	510592	81.67	568
DEEP PIT	SJ59SW	14	351270	394800	27.43	405.91
DENABY COLL.	SK49NE	11	449301	399748	21.34	733.81
DERWENT BRIDGE	SE73NW	11	470890	436103	4.35	1060.37
DITTON	SJ48NE	7	349750	386910	25.53	899.62
DODDINGTON/HARBY STATION	SK87SE	2	487595	371404	7.62	1098.51
DOGTON NO1 BORE	NT29NW	344	324200	696890	81.07	234
DOLES LANE WHITWELL	SK57NW	5	453594	377491	88.4	347.78
DON PEDRO SHAFT (WHITWOOD)	SE42SW	57	440400	422820	38.1	428.07
DOUGLAS BH.76 DIAMOND	NS83SW	94	284905	632685	*	868
DOUGLAS,HAPPENDON BH.1	NS83SE	19	285890	633530	183	*
DRAX BORE NR NEWLANDS RAWCLIFFE	SE72SW	33	470110	424930	*	1001.27
DRILL COLLIERY	SJ22NE	8	328000	327000	*	219.45
DRUM GRANGE BH. NRTH OF NO9 PIT	NS41SE	29	245133	610679	334	319
DRUMBOWIE FARM BH.2/57	NS41NE	56	246092	615208	182.8	270
DRUMCARRO NO5 BORE	NO41SE	39	345910	712900	170.08	241
DRUMJOAN NO.1 BORE (1959)	NS41NE	31	246059	616741	158.01	499
DRUMLEY BH.1	NS42NW	14	240536	625248	57	312
DRUMLEY ROADEND	NS42SW	3	241014	624930	65	317
DUDLESTON	SJ33NW	19	334150	337840	96.66	848.79
DUDLESTON A5/5/1	SJ33NW	BJ	334990	337560	96.66	848.79
DUKE PIT HOWGILL	NX91NE	10	296980	518075	*	260.73

DUKE'S COTTAGE, BOREHOLE	SK55SE	16	457428	350041	77.1	694.72
DULAIS VALLEY No.2 BH	SN70NE	34	279670	205270	131.98	694.94
DUMBARNIE NO10 BORE	NO40SW	54	344815	703230	44.74	224
DUNHOLME 1	TF07NW	21	500856	379196	31.7	*
DUNSTON 1	TF06SE	2	507398	363126	12.5	*
DYKE	SJ34NW	46	332982	348843	68.16	315.47
DYKEFIELD PIT BH.2	NS42NE	11	249675	629374	135	212
EADY FARM, BOTTESFORD	SK73NE	9	479582	337128	32.35	765.77
EAGLE COLLIERY ROWLEY REGIS	SO98NE	22	396340	286560	140.8	210.92
EAGLE RAISING & FINISHING CO	SD91SW	11	391263	414874	*	221.59
EAGLEY	SD71SW	36	370050	414850	*	333.45
EAKRING 1	SK66SE	1	467738	362552	90.83	*
EAKRING VILLAGE	SK66SE	123	466965	362673	90.6	*
EARDINGTON	SO78NW	3	371350	289990	60.96	304.19
EARLESTOWN	SJ59SE	5	359010	394790	18	760.78
EAST CARRON	NS88SE	222	288678	682609	5.06	598
EAST MACHRIHANISH NO.1	NR62SE	8	165610	621350	*	224.93
EAST PIT UPCAST SHAFT, GWAUN CAE GURWEN	SN71SW	14	272800	212120	N/A	416.13
EASTFIELD BH.1A	NT37SW	246	332647	672971	*	1028
EATON	SK77NW		471030	378100	19.81	997.11
ECCLESTON	SJ36SE	17	337465	364176	20.25	739.01
ECCLESTON 2	SJ49SE	14	348573	394096	64.01	450.04
EDGMOND 1	SJ72SW	BJ	370160	322150	0.87	270.35
EDWALTON	SK63NW	37	460450	335780	28.96	457.2
EDWALTON-MELTON ROAD	SK53SE	1	459680	334270	36.98	234.65
EGGERTON BORE	NS83SE	39	285041	631706	229.77	*
EGMANTON 1	SK76NE	1	475520	368430	34.34	*
EGMANTON 68	SK76NE	73	475779	368222	38.4	2162.5
ELDON COLLIERY	NZ22NW	5	423922	528091	*	*
ELLENBOROUGH COLL.	NY03NW	56	303655	535605	*	>284
ELLINGTON COLLIERY	NZ39NE	27	435626	596835	176.5	212.24
ELSCAR MAIN COLL.	SE30SE	12	439021	400289	54.86	486.87
ELSTON GRANGE	SK74NE	2	478202	346008	15.04	842.2
EMMA MINE DOWNCAST SHAFT	NZ16SW	23	414398	563896	*	171.64
ENSON	SJ92NW	32	394340	328950	80.77	1017.65
ENTERKINE BH. 7	NS42SW	14	241458	623256	55	209
ERBISTOCK	SJ34SW	35	334767	343213	63.39	1888.4
ESKMOUTH BORE	NT37SW	31	334530	673320	*	1042
EVERTON	SK79SW	22	470175	392959	5.49	2078.76
EVERTOWN	NY37NE	14	336390	575938	92.8	777
EXHALL COLLIERY DOWNCAST EXHALL	SP38NE	10	435720	285470	101.8	265.73
FAIRFIELDS	SK21NW	10	423263	317627	62.28	753.16
FARLEY'S WOOD 4	SK77SW	40	470509	371949	37	*

FARMBOROUGH PUMPING SHAFT	ST66SE	1	365760	160110	131.06	438.91
FARNDON 1	SK75SE	1	477160	353500	12.8	*
FARNSFIELD 2	SK65NW	4	464023	356375	55.96	792.48
FARNWORTH	SJ58NW	26	352550	387310	33.12	914.6
FARNWORTH STATION	SJ58NW	37	351100	386980	31	718.95
FELINFRAN No.1 BH	SS79NW	71	270353	199600	59.26	1021.54
FERN HILL	SP27SE	29	425098	270475	96.76	1083
FERNEYRIGG	NY98SE	13	395790	583640	237.13	457.5
FFALDAU VICTORIA	SS99SW	8	290170	191720	160.7	336.78
FFYNON WEN BH (Nantgarw 'A')	ST18NW	5	311542	186794	97.93	759.26
FIDDLERS	SJ92NE	8	395918	325425	124.75	913.5
FINCH FARM	SJ49SW	2	341927	393177	*	546.05
FIR TREE	SE73SE	3	478304	432915	4.55	1067.13
FIRBECK MAIN COLLIERY	SK58NE	1	458240	385970	35.78	783.06
FIRTH OF FORTH SEALAB NO1A BORE	NT38NW	31	332299	685678	-43.59	594
FIRTH OF FORTH SEALAB NO2 BORE	NT38SW	1	332723	684489	-22.8	544
FIRTH OF FORTH TOWER NO1 BORE	NT38NW	1	330024	687894	15.94	963
FIRTH OF FORTH TOWER NO2 BORE	NT38NW	2	331563	687394	14.33	549
FIRTH OF FORTH TWR.BH3WELLESLEY	NT39NE	43	339617	698271	-14.63	691
FISHERWICK	SK10NE	8	417353	308449	*	961.13
FISHPOOL	SK55NE	3	456939	355389	111.56	821.54
FISKERTON	SK74NW	9	472939	349792	13.75	833.8
FISKERTON 1	SK74NW	10	473546	349826	18.52	*
FLAWFORTH OLD CHURCH	SK53SE	15	459307	333139	46.71	309.37
FLEET	TR36SW	64	630800	160050	3.05	597.71
FLINT MILL	SK21NW	7	424910	319310	53.04	609.6
FLOUR MILL 3	SO60NW	8	360440	206850	100.89	178.74
FLY COLLIERY ROWLEY REGIS	SO98NE	21	396160	286710	138.42	214
FOLKESTONE	TR23NW	38	624030	136750	34.66	1036.47
FOREST HILL	SK58SE		459880	381380	56.36	903.95
FOREST STONE	SK55NE	15	455742	358073	128	891.03
FORYD	SH97NE	2	299450	379990	4.9	227.53
FOSS WAY STRAGGLETHORPE	SK63NE	1	466570	336190	37.62	901.98
FOSTERTON BORE,LANDS OF RAITH	NT29NE	24	325642	696458	57.91	229
FOUDRY BRIDGE	SU76NW	58	470630	166020	49.35	828
FOUR OAK	SJ58NW	71	354586	387095	23.26	1150.28
FOXFIELD SH	SJ94SE	7	397650	344650	*	229.28
FOXHUNTER	SJ92SE	11	399748	320090	159.41	370.94
FRANCES COLL.1/77 D11 MAIN GATE	NT39SW	90	331928	690553	-776.94	208
FRANCES COLL.2/71 BH1 MAIN GATE	NT39SW	54	331785	691752	-540.72	204
FRANCES PIT	NT39SW	43	332065	692415	-404	*
FRANCES PIT SEA MINE	NT39SW	41	332080	692405	-280	*
FRANK SHAFT NEWDIGATE COLLIERY BEDWORTH	SP38NW	2	433460	286930	111.28	476.34

FREESMAN BH.1	NS41NE	10	245761	618333	109.6	327
FRICKLEY COLL.	SE40NE	17	446480	409570	38.1	630.61
FRICKLEY COLL. UGBH 1	SE40NE	2	446480	409570	*	853.25
FRYSTON COLLIERY	SE42NE	9	445644	426967	22.67	523.06
FULLARTON BH.	NS32NW	2	233800	629800	14.6	283
FULLEDGE COLLIERY	SD83SW	17	384562	432293	*	298.4
GAINSBOROUGH 1	SK89SW		483260	390260	30.17	1739.21
GAINSBOROUGH 2	SK89SW	2	481770	390790	31.78	*
GANABRIG LODGE	SK57NW	41	454751	375055	54.68	223.28
GARTENKEIR FARM BORE	NS99SW	290	292665	694860	67.83	487
GARTLOVE NO1 BORE	NS99SW	226	294545	693337	70.6	457
GARTLOVE NO2 BORE	NS99SW	292	294024	692670	50	404
GARTSHERRIE DIAMOND BORE	NS76NW	98	271095	666900	88	571
GATEWEN COLL 1 PIT	SJ35SW	9	331340	351680	*	233.32
GATRA 2	NY02SE	19	307000	520930	140	308.58
GEDLING COLL.	#	#	461200	343900	56.39	429.16
GENERALISED SAUNDERSFOOT AND STEPASIDE	SN10NW		214000	207000	30	415.21
GILLMOSS	SJ49NW	24	340610	396130	-	691.94
GLENBERVIE 2	NS88SE	43	285515	683880	32	718
GLENBERVIE NO1 DIAMOND BORE	NS88SW	204	284445	684570	30.35	635
GLENOCHIL NO1 BORE 1978	NS89NE	100	287694	696173	9.83	642
GLENTWORTH 1	SK98NW	1	493120	388059	25.78	*
GLENZIERFOOT BORE	NY37SE	2	336514	574275	64.93	869
GLOUCESTER WATERWKS OXENHALL	SO72NW	1/A	370920	226440	*	362.71
GLYNCORRWG COLLIERY, SOUTH PIT	SN80SE		288800	200020	270.79	372.47
GOLBORNE	SJ69NW	1	360484	398270	*	246.89
GOLDEN VALLEY OLD PIT	ST67SE	26	369010	170800	35.1	137.2
GOOSEDALE FARM BH	SK54NE	22	456380	349420	90.65	669.47
GORDON ROAD BLYTH BOREHOLE	NZ38SW	11	431700	580540	4.21	362.4
GORSWOOD HALL COLLIERY, SHAFT NO.7	SD50SE	52	357677	400919	63.4	490.22
GORWYDD COLLIERY, GOWERTON	SS59NE	21	259600	196010	*	235.1
GRACEFIELD LANE	SK76NE	75	479547	369579	9.95	950.6
GRANBY 1	SK73NE	4	475320	336840	38.1	*
GRANGEMOUTH DOCK BORE	NS98SE	13	295132	683872	4.5	1374
GRANVILLE	SK31NW	1	430700	319070	*	408.71
GRANVILLE COLLIERY NO.8	SO98NE	35	396460	285710	156.66	258.85
GRASSMAINSTON BORE NO1/77	NS99SW	294	292597	693235	46.21	537
GREAT FRAMLANDS	SK72SW	46	474572	322289	138.38	893.56
GREAT HECK	SE52SE	4	458668	421552	13.13	824.79
GREAT PONTON 1	SK83SE	540	489395	330530	134.8	*
GREEN LANE COTTAGES BOREHOLE AT EMBLETON	NZ42NW	1	440954	529933	87.96	312.12
GREEN LETCH BURN NETHERTON	NZ28SW	72	424800	582880	36.42	277.03

GREENBRIDGE	SJ48NE	26	346640	385535	11.14	757.66
GREENHOUSE FARM	SJ49SE	44	348481	392304	66.66	827.99
GREENWAYS FARM MERIDEN	SP28SE	139	425800	280600	*	*
GRESFORD COLL	SJ35SW	7	333820	353640	*	689.71
GRIFF COLLIERY 4 SHAFT	SP39SW	10	434970	290550	104	212.5
GRIMETHORPE COLL. No. 2 SHAFT	SE40NW	63	440945	408360	35.36	786.16
GRIMMER	SK73SE	50	479077	334037	47.26	710.65
GROSFAEN COLLIERY, PEN-Y-GARREG (WEST) PIT	SO10SW	2	313390	200600	*	620.23
GROVE PIT	SN10NW	8	213900	207120	*	191.36
GUNBY LEA 8	SK21SE	6	429120	314590	87.48	365.96
GWERSYLLT COLL 1	SJ35SW	16	331646	353714	*	237.08
HADENHILL COLLIERY ROWLEY REGIS	SO98NE	34	396040	285730	137.17	224.02
HADLEYGATE	SK02SE	2	407530	320300	97.54	534.9
HAFOD Y BWCH 1	SJ34NW	18	331180	346570	*	553.95
HAGGMUIR BORE	NS76NW	72	274065	668770	188	528
HAIG 7 UP	NX91NW	5	292470	516820	*	*
HAIG COLLIERY 11	NX91NW	13	291565	519282	*	*
HAIG COLLIERY 13	NX91NW	11	291750	518370	*	153.01
HAIG COLLIERY NO 15 UG BH	NX91NW	15	290590	518004	*	*
HALBEATH DIAMOND BORE	NT19SW	519	312450	690135	152	200
HALE	SJ48SE	18	347077	383134	9.79	1155.56
HALLMARK BH.	NS42NW	9	243912	628929	90	686
HALLSIDE COLLIERY	NS65NE	1	266960	659680	39	451
HALLSTEADS	SE40NW	110	441952	409119	67.72	466.83
HALTON HOLEGATE	TF46NW	18	543061	365242	15.24	*
HAMBLETON 1	SE53SW	43	454155	431264	7.52	457.2
HAMSTEAD 1 GREAT BARR	SP09NE	7	407600	296250	160.03	949.05
HAMSTEAD 3 GREAT BARR	SP09NE	6	407280	297780	167.64	986
HANDSACRE	SK01NE	59	408837	315577	72.98	726.31
HANGE COLLIERY PIT NO.9 ROWLEY REGIS	SO98NE	65	397020	289970	190.99	207.87
HANYARDS	SJ92SE	12	396484	324255	107.05	846
HAPPENDON WOOD BORE	NS83SE	38	285102	633828	206.59	*
HARBY EAST	SK73SE	56	475549	331286	55.36	679.5
HARBY HILL	SK72NE	44	476437	327055	806.85	*
HARDWICK BECK	SE41NW	38	441790	418080	38.4	442
HARLEY	SJ83NW	7	383676	339316	182	1103
HARRINGTON COLLIERY 10	NX92SE	6	298046	521543	53.95	205.13
HARRINGTON NO.10 COLLIERY NO.8 U/G UPBORE	NX92SW		294852	522542	*	*
HARRY STOKE B	ST67NW	10	363210	178160	46	689
HARSTON ROAD	SK83SE	532	485173	331944	790.74	*
HARTLEPOOLS LIGHTHOUSE POINT BH	NZ53SW	50	453191	533873	*	392.28
HARTON 1	NZ36NE	80	439660	565620	20	*

HARWELL HW3	SU48NE	92	446801	186441	122.3	551
HARWORTH SH 1	SK69SW	3	462499	391244	33.76	883.6
HATFIELD COLL. No.1 SHAFT	#	#	465300	411300	5.36	805.6
HATFIELD MOORS 3	SE70NW	17	470383	406669	8.84	*
HAUGHTON	SK67SE	41	466746	373088	35.36	584.45
HAUGHTON HALL	SK67SE		468595	373305	25.18	898.71
HAUNCHWOOD SHAFT TUNNEL PIT	SP39SW	17	431450	291700	125.88	339.7
HAWKESBURY COLLIERY EXHALL	SP38NE	11	436200	285460	96	257.86
HAXEY/SOUTH CARR	SK79NW	1	472419	396772	5.48	973.92
HAYFIELD FARM	SJ58NW	477	354340	388490	18.4	1132
HAYHILL BORE	NS41NE	39	246448	616119	167.7	205
HAYTON 1	SE84SW2	2	482597	444512	*	1164.94
HAYTON SMEATHE	SK78SW	42	471440	383390	9.14	954.34
HAZEL GROVE	SJ98NW	11	391820	386550	0.9	559.31
HEATH SIDE	SJ58NW	476	354179	389275	22.68	912.18
HEATON PARK	SD80NW	19	383540	405170	91.44	723.03
HEATON PARK GRAND LODGE	SD80SW	9	382700	403290	85.2	625.43
HEBBURN COLLIERY PIT C	NZ36NW	62	430700	565200	24	319.63
HEMPSHILL COLLIERY NO.3 PIT	SK54SW	36	452650	344490	74.68	252.71
HEMSWELL 1	SK98NE	8	495433	389788	53.07	*
HENNYMOOR	SK57SW	82	454440	374490	60.33	658.38
HENRY PIT (WILLIAM NO.2 PIT) - WCC NO.9	NX91NE	171	297300	518900	*	279
HESKETH SH	SJ85SE	2	388484	353319	176.84	593.29
HESWALL	SJ28SE	1	325260	381610	6.1	1018.6
HEWLET 1	SD60NW	43	363707	405377	*	427.33
HEY SPRINK	SJ74SE	32	378780	343355	128.17	950.15
HIBALDSTOW 1	SE90SE	112	498943	403924	9.2	*
HICKLETON MAIN COLL.	SE40NE	16	446471	405314	50.29	831.65
HIGH COGGES WITNEY	SP30NE	86	436670	209218	84.6	1151
HIGH KNOCKMURRAN BH.2	NS41NW	131	244408	615496	142	357
HIGH MARNHAM 1	SK87SW	4	480920	370290	11.2014	*
HIGH MONKCASTLE	NS24NE	53	228860	647810	76.2	264
HIGH WALTON	NX91SE	209	298530	512696	103.88	424
HIGHHOLM NO4 BORE	NT19SW	454	311725	690405	157	276
HIGHLEY	SO78SW	6	374260	282920	91.44	506.88
HILLS FARM	SK73SW	5	470987	332329	29.86	676.7
HOBBERGATE	SJ93NW	10	391300	337400	*	498.95
HOBSLAND BORE	NS32NE	1	235746	629935	29.5	306
HOLDEN CLOUGH COLLIERY BIRSTALL YORKS	SE22NW	17	423540	427290	*	247.23
HOLDEN DIKE	SE64NW	202	461723	446080	8.81	923
HOLLAND BORE NO11	SD40SE	15	349901	402750	*	256
HOLLIES BARN OXFORDSHIRE	SP43SW	25	441870	234350	134.38	1076
HOLLY BANK COLL. UNDERGROUND SHAFT	SJ90SE	1	395500	304370	-252.7	317

PIT						
HOLLY BANK COLLY 5	SJ90SE	19	396620	303410	167.64	366.73
HOLMES HOUSE	SP45NW	5	440755	256704	91.45	1016.12
HOLTS BARN	SJ93NW	2	390055	336420	123.44	1219.25
HOOK 1	SM91SE	13	198990	211920	12.5	39.62
HOOK COLLIERY 2	SM91SE	14	199020	211770	21.82	102.11
HOOK COLLIERY 3	SM91SE	16	199180	211760	14.89	94.66
HOOK COLLIERY 4	SM91SE	15	199100	211820	15.25	67.16
HOOTON PAGNELL BH	SE40NE	68	447382	408054	41.96	553.11
HOPTON POOL	SJ92NE	2	395200	325950	116.13	1063.45
HOPYARD LANE	SK75NE	152	477752	358627	12.05	608.11
HOUGH GREEN	SJ48NE	25	348030	387290	17.4	400
HOUGHTON MAIN	SE40NW	10	444287	406343	30.48	728.35
HOULDSWORTH PIT	NS41SW	69	242433	611882	235.7	375
HOYLAND SILKSTONE COLL.	SE30SE	10	436953	401468	141.73	464.9
HOYLE BANK	SJ18NW	1	311482	388772	23.5	668.76
HUCKNALL 2 COLLIERY 5 SHAFT	SK54NW	28	454030	349000	72.24	577.9
HUNGRY LANE BOREHOLE	SK10SW	96	413754	304069	95.39	1223
HUNTERSTON NO.1/60 BORE	NS42SE	16	246260	621590	110.27	754
HUNTHOUSE SH 1	SO77SW	1	370050	270570	155	81.23
HURLET	NS56SW	333	251110	661230	30.31	304
HURSLEY HILL	ST66NW	13	361800	165650	67.2	575.9
INCHDAIRNIE NO2 BORE	NT29NE	1	325056	698930	79.25	423
INGLE HILL BOREHOLE	SK10NW	90	413789	306891	104.69	1076.77
INGLEWOOD BORE (1983)	NS89SE	203	288039	694293	56.9	583
INVERESK NO.75 BORE	NT37SW	50	334980	671940	*	245
ISABELLA PIT COWPEN COLLIERY	NZ28SE	99	429960	580690	15.17	274.21
IVY COTTAGE	SJ58NE	40	357072	389621	18.42	1110.1
JACK TAR PIT SCREMERSTON	NU04NW	4	401020	648470	*	206.02
JACKLEGS	SJ59SE	49	357618	391651	14.4	1102.87
JAMES CHADWICK & BROS EAGLEY MILLS	SD71SW	4	371682	413137	*	205.13
JARROW COLLIERY PIT E OR DEEP PIT	NZ36NW	20	433130	565462	16.76	352.98
JEWEL MILL A4/8	SD83NW	8	383750	436030	98.93	344.2
JUMP COLLIERY ROWLEY REGIS	SO98NE	56	396770	286120	175	265.2
KELFIELD RIDGE	SE63NW	1	460825	439597	7.62	967.51
KELHAM	SK75SE	8	477170	353860	12.19	798.28
KELHAM HILLS 2	SK75NE	2	476050	357220	49.68	*
KELLINGTON BH	SE52SW	2	454630	424850	12.79	688.01
KELTYBRIDGE 1	NT19NW	187	313377	695450	147.98	454
KEMIRA 1	SJ47NE		347586	376421	8.99	1438.05
KENSTEY FARM BORE	NS52SW	21	252646	624401	152.1	605
KERSE BH.1/79	NS41SW	211	242697	613313	210.9	416
KERSE BH.2/79	NS41SW	212	242754	613649	205	293

KIBBLESTONE	SJ93NW	60	391079	336371	195.94	1162
KILCONQUAR MAINS NO1 BORE	NO40SE	26	348448	703046	22.9	830
KILGETTY	SN10NW	9	213500	207740	*	310.90
KILLOCH NO.1 BORE	NS42SE	8	247580	620240	155	625
KILLOCH NO.1 SHAFT	NS42SE	9	247890	620440	156	758
KILLOCH NO.2 SHAFT	NS42SE	10	248000	620480	157	737
KILMAIN BH.1 DIAMOND	NS41SE	21	245070	611327	345	220
KIMBERLEY COLL.	#	#	450352	344016	128.02	260.81
KINCARDINE BRIDGE BORE	NS98NW	40	291660	687150	4	1209
KINCARDINE EAST LONGANNET COLLIERY	NS98NW	230	293900	686400	4	500.17
KINETON	SP35SE	19	438442	250155	*	350.21
KING PIT	SJ59SW	1	350500	392120	60.96	463.19
KING PIT HOWGILL COLLIERY	NX91NE	4	296660	517900	c.68	302
KINGENCLEUGH BH.1	NS52NW	12	250286	625971	120.4	1018
KINGLASSIE	NT29NW	171	322970	697920	70	583
KINGSDOWN	TR34NE	5	637170	149220	14.7	918.67
KINGSDOWN PIT PARK HALL COLLIERYS	SD60NW	11	362698	409860	*	279.2
KINGSHAUGH HOUSE	SK77SE	9	475536	373123	26.47	966.18
KINLET	SO78SW	3	372710	281730	*	204
KINNEIL COLLIERY NO2 SHAFT	NS98SE	55	298787	681267	5	879
KIRKBY COLLIERY PIT NO.1	SK55NW	4	450391	357000	155.54	325.89
KIRKCALDY HARBOUR BORE	NT29SE	21	328426	691970	3	241
KIRKCALDY NO 1 BORE	NT29SE	11	328765	692360	8	*
KIRKLINGTON	SK65NE	129	468800	356020	28.9	731.65
KIRKTHORPE LANE BH	SE32SE	38	435611	420454	42.34	211.16
KIRTON	SK66NE		469880	369130	52.79	885.15
KNAPTHORPE G1	SK75NW	12	474287	358428	52.2	768.1
KNEESALL	SK76SW		471353	364380	87.93	834.86
KNENHALL	SJ93NW	86	391540	338230	171	1154.6
KNIGHTS LANE	SP25SW	1	422420	254970	42.7	366.29
KNOCKGULDERON BH.	NS41SE	27	248328	614248	268	383
KNOCKMURRAN BH.2	NS41NW	146	244791	615720	138.2	347
KNOCKSHINNOCH NO.12 BORE	NS41SW	139	242860	613440	205	324
KNOCKSHINNOCH NO.13 BORE	NS41SW	26	242400	613580	209.4	317
KNOTTYHOLM	NY37NE	6	339501	577124	42.67	649
KNOWL WALL	SJ83NE	1	385800	339385	128.93	644.04
LADBROOKE	SP45NW	6	441639	259584	82.35	901
LADY LEYS	SK21SW	4	424033	313936	84.97	754.7
LADY WINDSOR COLLIERY. DOWNCAST SHAFT	ST09SE	17	306286	194260	149.66	563.73
LADYSMITH SHAFT, CROFT PIT	NX91NE	16	296550	515940	87.52	333.45
LAMBHILL NO.2 BORE	NT09NW	12	300133	696201	107	895
LAMBHILL NO3 BORE	NS99NE	120	299452	696279	105.69	313
LAMING GAP NO.2 (PLUMTREE)	SK63SW	63	463815	331997	80.22	440.97

LANDS OF EAST SALTCOATS BORE	NS98SE	4	295125	682230	3.5	974
LANDS OF SOLGIRTH DIAMOND BORE	NS99SE	75	299707	694840	97	817
LANGAR 1	SK73NW	4	471995	335572	31.7	*
LANGLAND BORE	NS32NE	11	238270	629699	45	275
LANGTOFT 1	SE96NE	4	499340	465156	140.67	*
LANGWITH COLL.	#	#	452900	370700	94.12	517.43
LARK HILL	SJ69NE	22	368990	396820	22.62	1266.5
LATHALLEN DIAMOND BORE	NO40NE	43	346490	705800	137	247
LATHALLEN DIAMOND CONTINUATION	NO40NE	51	346440	705800	137	431
LAWN SPINNEY	SK02SE	3	406215	320272	85.48	548.11
LAXTON	SK76NW	36	471599	367119	78.05	915.83
LEDSHAM 11	SE43SE	25	446446	431534	*	*
LEDSHAM 2	SE42NE	27	446567	429785	49	225.25
LEDSTON LUCK COLL.	#	#	442954	430790	81.67	288.9
LETHAM NO.2 BORE	NO30SE	9	337930	704620	99	289
LEVEN PIT	NO30SE	130	337410	700040	30	265
LIGHTMOOR DEEP	SO61SW	7	364140	212110	176.17	285.29
LILLESHALL 6	SJ71SE	BJ	377700	313950	1.1	854.96
LILLESHALL 7A	SJ71SW	1	374000	312735	149.05	469.39
LINACRE	SK37SW		432900	372600	163.07	367.34
LINBY COLL.	#	#	453560	350440	91.85	418.92
LINGARD LANE PIT 1	SJ99SW	9	391890	392540	89.92	369.11
LINGLEY	SJ58NE	41	355604	389166	17.84	1130.33
LINKFIELD	NS88NE	217	288586	686475	12.23	560
LINTON WOODS	SE56SW	12	450228	463044	16.44	708.1
LITTLE BLITHE	SK02SE	25	409416	321302	76.09	443.03
LITTLE HAY	SK10SW	13	411706	302331	*	1186.78
LITTLE PILMUIR NO1 BORE	NO40SW	53	340725	703930	36.42	371
LITTLE SPIERSTON BORE	NS42SE	5	247340	622540	98	872
LITTLEBOURNE	TR15NE	13	619620	157570	41.1	797.97
LITTLEMILL BH.1/60	NS41SE	59	245133	614955	168	237
LLANEDI	SN60NW	1	260952	207477	26.99	1041.2
LLANTRISANT COLLIERY NO.1 PIT	ST08SW	8	303320	184100	*	640.1
LLAY 2	SJ35NW	4	334060	356520	*	256.03
LLAY HALL	SJ35NW	6	333040	355770	*	662.94
LLAY HALL COLL 2 SH	SJ35NW	5	331530	355160	*	366.9
LLAY MAIN COLLIERY 1	SJ35NW	1	332790	356480	*	827.3
LLETTY SHENKIN, UPPER PIT	SO00SW	10	302960	201270	177.53	269.62
LOCHHEAD BORE	NT39NW	136	332165	696570	44	1167
LOCHHEAD PIT AND BORE	NT39NW	228	331840	695865	59	*
LOCHILL BORE	NS42NE	7	248000	629520	120	398
LOCHLEA FARM BORE	NS42NE	1	245354	629786	108	207
LOCHSIDE	NS61NW	188	260441	615030	189.4	529

LOCHTY BORE,INCHDAIRNIE	NT29NW	357	324270	698300	67.36	396
LOCHTY NO2 BORE	NO50NW	35	352335	707530	118	226
LOCHTYSIDE BORE	NT29NE	17	329467	698733	56.39	322
LODGE PLANTATION	SK76NE	72	478234	366769	20.15	875.54
LONG CLAWSON 2	SK72NW	13	472452	325658	124.9	*
LONG MEADOW WOOD	SP27SE	30	427164	274146	101.18	1152.22
LONGANNET NO.1 BORE	NS98NE	119	295150	687680	56.11	337
LONGFORD (PARKSIDE COLLIERY)	SJ69SW	51	360330	390010	9.1	1260.65
LONGHEDGE LANE	SK74SE	3	479446	340972	24.39	821.1
LONGHIRST COLLIERY 1 PIT	NZ28NW	23	423830	589080	39.01	212.95
LORD BRUCE NO4 PIT, BLAIRHALL	NT08NW	50	300390	688560	53	614
LOUDENSTON FARM	NS42SW	107	243753	621023	87	253
LOUDUNSTON FARM BORE	NS42SW	89	243465	621427	82.3	218
LOVELS HALL	SJ48SE	210	347964	384935	12.8	1095.2
LOWER HOUSE	SO62NE	5	369880	226290	39	262
LOWER LARGO TO LUNDIN LINKS	NO40SW	56	342480	702425	2	242
LULLINGTON	SK21SW2		424200	312500	*	*
LUMBY	SE42NE	29	448608	429990	33.35	335.58
LYE CROSS COLL	SO98NE	216	396990	288900	249	236.37
LYMESIDE HOLLINWOOD	SD90SW	23	391055	401980	*	495.91
MACKIES MILL FARM BORE	NT39NW	16	330510	697940	47	1252
MADDLE FARM	SU38SW	13	430530	182330	152	1200
MADELEY WOOD 1	SJ70NW	16	373870	308760	106.68	502.39
MADELEY WOOD 1	SJ70NW	16	373870	308760	108.51	502.39
MADELEY WOOD 5	SJ70NE	1	375000	306280	*	500.13
MAER	SJ73NE	3	376030	339340	122	1269.54
MAERDY No.3 PIT	SS99NE	19	296370	199870	324.31	457
MAGGIE DUNCANS HILL NO1 BORE	NS99SW	227	294183	690536	77.7	534
MAINBAND COLLIERY BH WA13	NX91SE	248	298113	513682	37.15	204
MAINBAND COLLIERY BH WA2	NX91SE	235	298153	513924	57.55	205
MAINFORTH COLLIERY NUNSTAINTON NO.2 BOREHOLE	NZ32NW	2	426217	535358	91.44	335.13
MAINSHILL BORE DOUGLAS	NS83SE	40	285789	632520	212.37	*
MALLDRAETH MARSH, ANGLESEY NO.1	SH46NW	1	241590	368810	2.4	74.07
MALLDRAETH MARSH, ANGLESEY NO.2	SH46NW	2	242550	368500	2.4	231.65
MALLDRAETH MARSH, ANGLESEY NO.3	SH46NW	3	243590	369130	2.74	398.98
MALTBY COLL. No.2 SHAFT	#	#	455083	392453	78.87	759.73
MALTHOUSE	SK68NE	34	466400	387621	8.89	1037.22
MAMBLE SH 1	SO67SE	16	369400	271410	161.24	62.18
MANOR BORE 1910	NS89SW	16	282915	694955	3	421
MANOR FARM	SP45NE	8	448400	256610	139.21	920
MANSFIELD COLL. No.2 SHAFT	#	#	457020	361450	117.61	515.07
MANTON COLL.	#	#	460700	378200	43.59	660.81
MANVERS MAIN No. 1 SHAFT	SE40SE	15	445341	400616	25.75	257.86

MANVERS MAIN No. 4 SHAFT	SE40SE	16	445357	400680	24.83	608.3
MARCHON BH NO. 18	NX91SE	199	296255	513802	56.35	211
MARCHON NORTH OF TARMFLATT HALL	NX91SW	1	294990	512670	*	653.19
MARCHWIEL	SJ34NE	1	335520	348730	*	776.02
MARGAM No.14 BH	SS88NW	26	282314	185834	106.82	559
MARKET WEIGHTON	SE83NE	7	485100	439130	*	944.96
MARKHAM MAIN COLL.	#	#	461700	404700	20.12	684.05
MARKHAM MOOR	SK77SW	3	471469	373768	22.09	954
MARSH COLLIERY	SJ27SW	383	324260	373440	*	246.87
MATSYARD COLLIERY STANTON & NEWHALL	SK22SE	18	428820	321070	*	482.49
MATTERSEY	SK68NE	16	468630	388980	7.51	1146.66
MAUCHLINE COLLY NO1 SHAFT	NS42NE	12	249678	629345	*	289
MEADOWHILL BORE	NS99SE	174	296124	693820	60.24	469
MEADOWHILL BORE,FOREST MILL	NS99SE	70	296165	694175	60	594
MEADOWS LANE	SK73SW	7	472828	330066	41.94	653.67
MEER END	SP27SW	10	424150	274700	96.76	1042.79
MEGGIE DEN BORE	NO30SE	3	336155	703055	79	561
MEGGOT FARM	TR24SE	10	625446	141066	139.4	1349
MEIRHAY C	SJ94SW	10	391950	343680	444.09	*
MELVILLE GRANGE B/H 2 (1986) ED	NT36NW	409	330574	667282	80.96	831
METHLEY MIRES BH	SE42NW	14	441110	426500	13.72	260.32
MICHAEL PIT EAST WEMYSS	NT39NW	330	333565	696125	10.67	254
MICHAEL PIT NO3 SHAFT	NT39NW	333	333630	696240	12.5	554
MIDDLE ROAD RADFORD	SP36SE	19	435124	261554	67.21	1256
MIDDLETHORPE (CAUNTON)	SK75NE	102	475223	359170	29.11	645.01
MID-STRATHORE BORE	NT29NE	29	328270	698274	50.6	674
MILFORD HALL	SE43SE	15	449739	430922	13.34	356.69
MILL HILL BINGHAM	SK73NW	48	470063	339238	53.08	621.71
MILL LANE CLIPSTON	SK63SW	8	464161	333841	80.92	574.85
MILLBAULK LANE, KNEESALL	SK76NW	42	470187	365327	86.27	855
MILNGAVIE BH.NO 5	NS57SE	50	257345	672845	33.55	756
MILTON 1	NS66NW	33	262000	667770	*	397
MILTON 2	NS66NW	34	262730	667790	*	474
MOCKERKIN 1 DEEP	NY02SE	135	308020	523200	114.99	226
MOCKERKIN 2 DEEP	NY02SE	136	308024	522873	108.26	214.88
MODDERSHALL	SJ93NW	53	392394	336319	158.85	1076.89
MONKTON HOUSE BORE NO.37	NT37SW	43	333250	670440	*	993
MONKTONHALL NO. 1 SHAFT	NT37SW	62	332240	670160	*	930
MONKTONHALL NO.1 BORE	NT37SW	34	334100	671080	*	295
MONKTONHALL NO.2 BORE	NT37SW	35	333990	671670	10.97	343
MONKTONHALL NO.2 SHAFT	NT37SW	63	332200	670280	43.28	921
MOON PIT, WEST OF WELLBANK RUBBER WORKS	SD51NE	18	357662	416322	*	281.33

MOOR FARM TROWELL MOOR	SK54SW	10	450620	340043	73.54	493.01
MOORFIELD PIT SHAFT	SD73SE	17	375760	431320	*	242.16
MORFA'R-YNYS BH	SS59NW		251880	199130	4.57	374.29
MORLEY BRIDGE	SJ47SE	15	346181	371455	13.62	1217.27
MORLEY MAIN COLLIERY	SE22NE	728	427108	428099	106.68	292.07
MORTON COLL / UG	SK46SW		441350	360400	129.85	674.58
MOSS HAGG BH	SE53SE	37	457278	433445	6.4	379
MOSS PIT 1	SD40SE	3	346354	404966	*	*
MOSS WOOD BORE	NT39NW	137	331085	696733	53	1029
MOSSBLOWN	NS32SE	6	239687	624901	40.9	226
MOSSBOG BH.1	NS42NE	3	246574	629666	114	434
MOSSWATER NO 1 BORE	NS77SW	23	274395	673570	76.6	372
MOSTON COLLIERY 1 PIT	SD80SE	59	388526	402363	*	346.73
MOUNT PLEASANT FARM BEDLINGTON	NZ28SE	52	428880	582720	11.89	349.3
MOUNTAIN COLLIERY No.2 BH	SN50SE		258879	200362	203.81	306.27
MUIRHOUSE 4	NS32NE	5	235570	628680	24	*
MUIRSTON BH.4	NS41NE	37	246625	616469	158	262
MUIRTOWN NO1 BORE	NT19SW	433	314777	692763	134	263
MURTON COLLIERY 2	NZ44NW	1	442460	546851	207.26	*
MUSSELBURGH NO.1 OFFSHORE BORE	NT37NW	2	334054	676058	39.6	1388
MUSSELBURGH NO.3 OFF-SHORE BORE	NT37NW	1	333409	675092	39.6	163
MUSSELBURGH STATION BORE	NT37SW	254	334004	672451	*	1008
N.C.B. A1/41 BH. BRENTWOOD	SJ89NW	341	380181	399442	60.36	607.16
N.C.B. ESKLEE BORE ROSLIN	NT26SE	177	327280	662040	185	551
N.C.B.BROACHRIGG EAST 1 & 1A RO	NT26SE	175	329209	660867	1771	645
N.C.B.ROWLEY ROAD WARKS	SP37NE	398	435060	275100	92.5	1004.94
NANT PIT	SJ35SW	5	330095	353316	*	252.02
NAPTON FIELDS WARWICKSHIRE	SP46SE	8	445140	261540	93.52	848
NCB BLACK CAT	SK96SW	17	490254	363990	23.4	*
NCB FAREWELL BH	SK01SE	18	408610	311870	105.86	876.27
NESTON COLLIERY SHAFT 1	SJ27NE	1	328990	376320	*	141.37
NESTON COLLIERY SHAFT 2	SJ27NE	2	329020	376310	*	103.71
NETHERSEAL	SK21NE	38	426750	315200	122.83	403.25
NETHERTON	NZ28SW	60	422750	581060	48	200.1
NEW BOWSON PIT	SO61NW	1	364380	215100	*	250.37
NEW FARM	SJ48NE	29	347632	386017	10.59	620.57
NEW HADEN	SJ94SE	20	399260	342180	183.49	317.35
NEW INGLETON PIT	SD67SE		369469	472328	*	*
NEW MONCKTON COLL No.6 SHAFT	SE31SE	3	437496	312193	65.46	489.59
NEW STUBBIN No.2 SHAFT	SK49NW	20	442720	396624	67.79	396.65
NEW YARD PIT	SD61SW	8	360117	411485	*	217.17
NEWARK 1	SK85SW	48	482900	352440	22	*
NEWBIGGIN COLLIERY 26\6	NZ38NW	45	432660	587810	-189.6	274.32

NEWBIGGIN NO 2 SHAFT	NZ38NW	33	430950	588600	4.59	281.02
NEWBOUNDMILL	SK46SE		449470	363470	121.31	299.62
NEWLANDS HOUSE	SK73SW	10	472142	333371	31.15	653.5
NO 1 BORE BALGOWNIE WOOD	NS98NE	21	298315	688129	76	398
NO 1 BORE EAST GRANGE	NS98NE	22	299068	688925	30	367
NO 1 DIAMOND BORE GLENCRAIG	NT19NE	439	318200	695600	*	379
NO 1 DIAMOND BORE PITKINNIE	NT19NE	265	319050	697180	90	532
NO 1 MARY PIT LOCHORE	NT19NE	15	317190	696370	100	615
NO 1 SHAFT SEAFIELD MINE	NT28NE	35	327690	689528	22.25	555
NO 1(700) DIAMOND BH CAPLEDRAE	NT19NE	14	318560	696900	102.61	730
NO 10 GRACE MARY COLLERIES P/NO2 ROWLEY REGIS	SO98NE	36	397130	289400	254.11	260.9
NO 11 PIT LUMPHINNANS	NT19SE	3	316220	694260	112	416
NO 2 BORE BLUE DIAL	NY04SE	1	307230	540660	*	711.71
NO 2 BORE WEST PARKFERGUS	NR62SE	6	166680	621730	*	405
NO 2 MARY PIT LOCHORE	NT19NE	16	317040	696485	105	535
NO 2 PIT & BH (431) MINTO COLL.	NT29SW	17	320510	694790	75	363
NO 2 SHAFT SEAFIELD MINE	NT28NE	34	327735	689379	20.12	535
NO 3 (UNION) PIT SEAHAM COLLIERY	NZ44NW	9	440900	549560	123	505.36
NO 3 BORE LOW KILKIVAN	NR62SE	10	165980	620890	*	221.59
NO 3 DIAMOND BORE WESTGRANGE	NS98NE	28	298580	689310	33	775
NO 3(K) BORE GLENCRAIG	NT19NE	425	318372	695245	75	237
NO 5 BORE MARYBURGH	NT19NW	43	313021	695877	159.86	320
NO 588 BORE INCHGALL FARM	NT19NE	7	318529	695803	88	467
NO 599 BORE, SPITTAL FARM	NT29SW	18	320840	694210	109.3	272
NO. 1 BORE BIGRIGG	NX91SE	122	299999	513974	82	404
NO. 2 PIT	NY01NW	280	301015	515466	*	*
NO.1 BORE BANBEATH	NO30SE	125	336580	701195	23	215
NO.1 BORE BARDARROCH	NS41NE	11	246533	618577	122.19	410
NO.1 BORE WEST TARELGIN	NS41NE	2	245732	619414	121.31	469
NO.1 WATER BORE LESSNESSOCK	NS41NE	36	248668	619407	132.21	477
NO.16 BORE LANDS OF MORTONMUIR	NS52SE	136	259840	623370	190	571
NO.2 BH OF DIAM BORING CO.ASPATRIA COMMON	NY14SE	5	316790	543490	*	210.01
NO.2 DIAMOND BORE EAST GRANGE	NS98NE	89	299541	688885	29.3	572
NO.5 SMITHSTON BORE	NS41SW	28	241960	612960	190	309
NO1 BORE CARDEN	NT29NW	317	322580	695620	82	228
NO1 BORE MANOR	NS89NW	8	282580	695145	6	270
NO1 BORE ROUGH PARK CLUNY	NT29NW	386	323420	695450	91	225
NO1 CASSINGRAY	NO40NE	76	348925	707270	182	235
NO1 DIAMOND BORE,BLACKGRANGE	NS89SW	1	283860	694880	7	581
NO1 PARKLANDS	NS99SE	5	296070	692420	76	1029
NO1 PIT FOULFORD	NT19SE	364	317270	692120	123.6	278
NO1 PIT KINGLASSIE	NT29NW	354	323770	698280	70.53	333

NO1 PIT, VALLEYFIELD COLLIERY	NT08NW	90	300950	686410	5	398
NO1 SALINE, SALINE SHAW FARM	NS99SE	56	299240	693402	88	745
NO1 SOUTH PIT WHITBURN COLLIERY	NZ46SW	4	440740	563670	33	521.61
NO1 SURFACE MINE KINGLASSIE	NT29NW	373	323910	697990	76.2	214
NO10 BORE STRATHRUDDIE	NT29NW	224	322110	697530	89	228
NO11 BORE DUNOTTER	NO40SE	18	346485	702520	23.13	300
NO1995 BORE WESTFIELD	NT29NW	465	320610	698450	69.89	227
NO1997 BORE WESTFIELD	NT29NW	467	320810	698640	78.36	215
NO2 BORE BOGSIDE	NT29NW	62	320930	698850	88.56	267
NO2 BORE CARDEN FARM	NT29NW	316	323390	696110	60.35	222
NO2 BORE HILLINGTON	NS56SW	51	252295	664145	15	221
NO2 SHAFT COMRIE COLLIERY	NT09SW	375	300660	690955	91.8	386
NO2 STEAM BORE LETHANS	NT09SW	21	301515	693415	99	520
NO2001 BORE WESTFIELD	NT29NW	470	320740	698680	86.92	207
NO2005 BORE WESTFIELD	NT29NW	472	320820	698860	88.79	218
NO2013 BORE WESTFIELD	NT29NW	478	321000	698920	92.8	306
NO3 PIT COWDENBEATH	NT19SE	375	316660	691520	126.4	221
NO3 PIT, POLMAISE,FALLIN	NS89SW	65	283870	691385	14.63	383
NO3 SALINE BORE,BANDSCOTSDRUM	NT09SW	262	300530	692115	85	710
NO3006 BORE WESTFIELD	NT29NW	479	320978	699030	123.33	*
NO5 SHAFT HAIG PIT	NX91NE	1	296740	517600	*	365.76
NO5 SHAFT POLMAISE COLLIERY	NS89SW	71	283775	691425	13.58	588
NO6 AITKEN PIT KELTY SHAFT SE	NT19SE	4	315530	694790	105	372
NO679 BORE WESTFIELD	NT29NW	458	320910	698790	86.5	212
NO8A BORE LANDS OF DALGINCH	NO30SW	101	331445	701510	53	208
NO9A BORE LANDS OF DALGINCH	NO30SW	102	331275	701560	53	226
NORLEY HALL COLLIERY	SD50NE	43	355400	405550	*	464.21
NORMANBY 1	SK88SE	12	487178	383778	19.41	*
NORNAY	SK68NW	12	462500	388700	12.27	1095.15
NORTH DALTON 1	SE95SW	6	493815	452770	65.84	*
NORTH DUFFIELD 1	SE63NE	16	469177	435235	6.74	994.7
NORTH DUFFIELD 2	SE63NE	17	468767	437404	7.49	1025.7
NORTH GREETWELL	TF07NW		501158	373921	38.38	*
NORTH HAININGS,NO1 BORE,BO'NESS	NS98SE	66	296340	680459	*	778
NORTH LEIGH	SP31SE	11	438790	214100	138.6	1028
NORTH SEATON 162	NZ28NE	45	428410	586260	25.53	391.05
NORTH SEATON COLLIERY NO 57	NZ38NW	47	432580	586660	-191.41	208.35
NORTHBROOK OXFORD	SP42SE	10	449940	222460	107.4	592.2
NORTHUMBERLAND OFFSHORE BOREHOLE FOR BATES COLLIERY NO.B9A	NZ48NW	2	440020	589969	-51.1	329.44
NORTON BOTTOMS	SK85NE	18	487254	359035	19.72	801.62
NORTON DISNEY	SK85NE	16	489512	359252	11.1	915.03
NORWOOD 1	SK65SE	2	469590	354970	*	929.64
NOS 1+2 PITS BOWHILL COLLIERY	NT29NW	315	321150	695660	88.4	434

NOSTELL COLL.	SE31NE	9	439970	317030	57.61	473.35
NUN MONKTON	SE45NE	37	449975	458132	13.71	594.35
NUNEATON COLLIERY NO.3 NUNEATON	SP39SW	20	433040	292110	107	237.57
NUNEATON COLLIERY NO.4 NUNEATON	SP39SW	21	433050	292070	109.42	220.52
OAKHAM COLLIERY P/NO25 ROWLEY REGIS	SO98NE	32	396000	289850	209	201.17
OAKLANDS	SK21NW	11	422810	316207	84.4	797.66
ODD HOUSES	SK63SW	73	464182	331295	80.44	429.35
OFFSHORE BOREHOLE NO.12	NZ44NE	27	449930	548958	17.28	719.79
OFFSHORE BOREHOLE NO.14	NZ37SE	2	439638	570766	-77.77	357.23
OGILVIE COLLIERY, SOUTH PIT	SO10SW	9	312070	202940	272.8	502.92
OLD BLACKHEATH COLLIERY HILL & CAKEMORE	SO98NE	57	397600	285920	185	305.38
OLD DALBY 1	SK62SE	14	468143	323703	98.5	*
OLD LANE	SK02SE	19	409733	320727	70.84	436.22
OLD LEESWOOD GREEN JONES PIT	SJ25NE	324	326700	359520	*	206.25
OLD LION COLLIERY ROWLEY REGIS	SO98NE	24	396090	286450	135	204.8
OLDHALL BH.1	NS33NW	172	234071	636403	9	202
OLIVEBANK NO.2 BORE	NT37SW	33	333440	672750	*	279
OLLERTON	SK66NE		465583	367969	41.07	694.93
OLLERTON COLLIERY No.2 SHAFT	#	#	466300	367500	51.82	512.04
ONSHORE BOREHOLE NO. 17	NZ53NW	2	451390	538749	28.5	536.45
ONTMAINS FARM BH.	NS42NW	20	244406	625433	98.5	655
ORCHARD FARM NO4 BORE	NS89SE	171	286470	692755	6	220
ORCHARDHEAD BORE (1956) F	NS98SW	64	292375	684120	3.7	1230
OVERTON	SE55NE	5	455817	455480	801.53	*
OVERTON BRIDGE	SJ34SE	21	335423	343834	42.52	1203.46
OVERTON STEAM BORE	NS99SE	78	299628	691077	100.45	723
OWTHORPE	SK63SE	12	466880	333400	60.96	619.44
OXTON	SK65SW		462450	351890	79.25	624.85
OXTON 1	SK65SE	1	466520	351870	95.7	*
PADDLESWORTH COURT	TR14SE	3	619900	140410	160.07	1141.39
PANNY PIT DUNNIKIER COLLIERY	NT29SE	12	328640	693020	46.19	219
PARK DRAIN	SK79NW	31	472042	399188	5.56	1055.9
PARK GUTTER DEEP	SO60NW	14	361410	206310	57.91	182.88
PARK HALL COLLIERY	SJ94SE	22	399320	344440	*	351.05
PARKEND 1	SO60NW	16	362140	208180	*	343.99
PARKHILL 1	SK75SW	23	470443	352847	60.8	*
PARKHOUSE	SJ92SE	9	397550	324900	93.88	909.37
PARKSIDE COLL 1	SJ59SE	36	359968	394734	30.22	810.77
PARSONAGE NO.2 PIT	SD60SE	32	365076	400599	29.87	829.4
PASTURE PLANTATION PLUMTREE	SK63SW	19	462806	333114	50.14	444.91
PATHHEAD TO SANDY CRAIG	NO50SW	31	353835	702110	3	436
PEARSONS COLLIERY ROWLEY REGIS	SO98NE	17	396160	287090	139.9	210.16
PECKFIELD COLLIERY	SE43SW	4	443860	432700	64.31	263.45

PEDENS PLACE	NS86SE	351	289861	662589	242	634
PEGGY WOOD BH SURFACE	SE41NW	47	441770	417160	58.61	773.66
PELTON FELL LOW MAIN SHAFT	NZ25SE	102	425330	551770	62.33	280.66
PEMBERTON COLLIERY	SD50SE	9	356090	403615	*	574.98
PENALLTA COLLIERY No.2 SHAFT	ST19NW	21	314157	195929	N/A	685.8
PENKETH	SJ58NW	40	354700	388340	21.41	975.05
PENKHULL	SJ84SE	16	387270	344950	137.77	464.21
PENKRIDGE BANK 10	SK01NW	11	401470	317390	131.29	248.58
PENTRE PIT, LANDORE	SS69NE	130	265470	195990	59.13	451.02
PENYDARREN No.1 PIT, DOWLAIS	SO00NE	57	307990	206230	334.67	225.02
PETTERIL BANK	NY44SE	77	346640	542700	*	207.2
PINEAPPLE	NS88NE	214	288698	688238	12.85	569
PITTEUCHAR BORE NO1	NT29NE	11	327890	699615	86.87	473
PITTEUCHER BORE NO2	NT29NE	12	328142	699590	80.77	274
PITTEUCHER BORE NO3	NT29NE	13	327880	699340	83.8	366
PLAINMELLER	NY76SW	8	370560	562640	*	242.32
PLAS POWER COLL. NO 1 SHAFT	SJ25SE	44	329985	351929	*	252.27
PLAS POWER COLL. NO 2 SHAFT	SJ25SE	44	329961	351938	*	252.65
PLAS THOMAS A5/4	SJ33NE	BJ	335090	339260	64.68	745.06
PLEASLEY COLL.	#	#	449800	364400	154.99	480.06
PLUMPTONS FARM	SJ48NE	27	348290	386520	18.15	620.57
PLUMTREE EAST	SK63SW	11	461719	332889	45.74	381.3
PLUMTREE FLAWFORTH HOUSE	SK63SW	13	460072	333356	41.64	337.11
PLUMTREE HOE HILL	SK63SW	10	461940	333590	39.93	655.62
PLUMTREE NORTH	SK63SW	9	461105	333448	43.89	347.32
PLUNGAR 1	SK73SE	1	477200	333470	64.82	*
PLUNGAR 22	SK73SE	51	477535	332115	66.44	955.55
POLLINGTON 1	SE61NW		460500	421500	7.62	915.32
PONKEY ENGINE PIT	SJ24NE	7	329650	346350	*	201.35
PONT LLIW No.1 BH	SN60SW		261460	201340	47.24	275.54
POPLARS FARM, GRANBY	SK73NE	10	476275	337221	36.92	764
POW BECK NO. 6	NX91SE	217	297512	513916	90.57	333
POW BECK NO. 7	NX91SE	218	297153	514088	70.88	280
POW BECK NO. 8	NX91SE	219	297441	513332	94.8	366
POWMILL	NS88NE	218	286758	686315	12.16	506
POYNTON	SJ98NW	12	393200	385200	*	393.06
POYNTON STATION	SJ98SW	2	391048	384134	*	860.83
PRESTWICK BURGH LANDS 3	NS32SW	1	234518	624928	13.7	203
PRISTON BH	ST66SE	2	369810	160630	76.78	278.05
PUMP LANE BH	SE41NW	37	441354	417668	42.2	433.43
QUARRY BANKS (LINBY) BH.	SK55SW	67	453711	352265	91.3	679.9
QUEENSLIE BRIDGE BORE (NO 1)	NS66NE	85	266300	666030	77.62	682
QUEENSLIE NO 6 BORE	NS66NE	179	268130	665235	78.47	626

QUEENSLIE NO2 BORE	NS66SE	49	265895	664900	36	764
QUEENSLIE NO3 BORE	NS66SE	50	267560	664900	62.53	716
QUEENSLIE NO4 BORE	NS66NW	326	264640	665975	78.2	732
RADFORD COLLIERY	SK54SW	26	454970	341010	35.8	262.74
RADWOOD	SJ74SE	28	377532	341761	137.91	1101
RAINFORD A2/70	SJ49NE	4	347490	399680	35.71	330.09
RAINFORD POTTERIES A2/78	SJ49NE	5	349052	399345	30.89	293.52
RAITH	NS32NE	20	239270	627048	54.8	383
RANSKILL 1	SK68NW	19	464234	388144	18.21	*
RANTON 1	SJ82SW	12	384410	323620	*	1859.28
RASHIEHILL (GS) BORE	NS87SW	22	283860	673005	152	1176
RASHIEHILL BORE	NS87SW	8	283600	673390	152	453
RAVENHEAD COLLIERY PIT 10	SJ59SW	18	351410	394340	35.17	496.65
RAVENSKNOWLE BH	SE42SW	59	444474	420455	57.54	358.9
REDDING DIAMOND	NS97NW	82	291575	677595	99	607
REDFORD BORE THORNTON	NT29NE	40	326490	696910	54.25	403
REDMILE 1	SK83SW	61	480860	334400	60.5	*
REDMILE BRIDGE	SK73NE	11	479469	335684	37.54	733.53
REDRAIG BORE	NS42NE	15	247484	627726	105.76	1036
RHODES BANK COLLIERY GAS STREET	SD90SW	5	393037	404825	*	363.63
RHUDDLAN 1	SJ07NW	28	301850	377300	*	*
RICCALL 2	SE63NW	35	461807	438246	9.18	811.35
RICCALL NO.1	SE63NW	23	461934	437310	7.21	707
RIDGEWAY	SJ85SE	14	389230	353810	182.98	559.31
RIGHEAD BORE	NS98NE	42	297165	688199	90.92	911
RINGWOULD	TR34NE	6	635290	148120	59.5	*
RISBY 1	TA03NW	83	501051	435774	51.36	*
RISCA COLLIERY No.1 SHAFT	ST29SW	8	321360	191610	82.6	307.64
RISEHOW 19	NY03NW	19	300190	536320	*	130.79
RISEHOW COLLIERY U/G 10 UP	NY03NW	5	301810	535350	*	*
RISEHOW COLLIERY U/G 7 DOWN 5 UP	NY03NW	3	301280	536040	*	469.88
RISEHOW COLLLIERY No 4 UNDERGROUND (DOWNBANK) BOREHOLE	NY03SW		302090	535070	*	-300.22 m BOD
RISEHOW NO. 17 UP 17 DOWN	NY03NW	6	300890	536140	*	456.62
RISEHOW NO.8 U/GR.B/H UPWARD & DOWNWARD	NY03NW	76&77	302300	535800	0	542.85
RISEHOW UP&DOWN 16	NY03NW	12	301386	535124	*	*
RISING SUN 1	NZ26NE	27	428210	567580	*	*
RISING SUN 2	NZ26NE	21	428790	568430	49.46	336.73
RISING SUN 2 SHAFT	NZ26NE	25	429820	568240	*	*
RNAD BANBEATH NO2 DD BORE	NS89SE	9	285790	692547	4.6	201
ROACHBURN	NY65SW	6	361640	559790	*	57.91
ROBROYSTON 1	NS66NW	12	263420	668900	*	230
ROBROYSTON NO.2 (NOT NO.1)	NS66NW	201	262810	668050	*	362

ROBROYSTON PIT	NS66NW	38	263080	668825	*	*
ROCKET	SK79NW	30	470421	397366	4.31	1139.06
ROCKINGHAM COLL.	SE30SE	13	435274	401100	129.54	312.93
ROCKS ESTATE 1 RED MOSS	SD60NW	12	364153	409557	*	326.14
ROMELEY HOUSE	SK47SE	154	447370	374990	86.87	502.62
ROOKERY	SJ85SW	2	381640	351740	167.64	240.21
ROSES FARM	SK73SW	8	471469	330725	48.44	621.6
ROTHES COLL NO1 SHAFT THORNTON	NT29NE	45	328120	697278	54.86	764
ROTHES COLL NO2 SHAFT THORNTON	NT29NE	46	327962	697267	54.86	644
ROTHES COLL. THORNTON	NT29NE	48	328088	697217	-432.2	437
ROTTINGTON ST BEES	NX91SE	210	295974	512493	*	268
ROWANBURNFOOT BORE	NY47NW	27	341031	575743	*	876
ROWLEY HALL COLL.	SO98NE	50	397500	287500	207	211.66
RUDDINGS	SK76NE	71	476862	369371	879.94	*
RUDDLE LANE BH	SK59NW	24	452127	395315	123.61	1058.32
RUDRY BH	ST18NE	1	318890	187380	99.95	486.92
RUDSTON 1	TA06NE	15	509340	466320	53.65	*
RUFFORTH AIRFIELD	SE55SW	20	453079	450308	17.38	574.57
RUNDLE BECK	SK73NE	13	475782	335242	33.36	748.52
RUSHLEY FARM MANSFIELF SURFACE BORE	SK55NW	21	454868	358396	155.92	248.18
RUSHOLME GRANGE	SE62NE	31	469694	426603	4.25	928.00
RUSKINGTON 1	TF04NE	1	509200	349746	10.97	*
RYDAL	SK01NW	66	404920	319514	69.01	344.86
RYTON 3	SP37NE	24	436940	275310	65.4	934.49
SALISBURY BANK	SJ18NE	1	315422	385325	19.28	942.1
SALSBURGH NO1A WELL	NS86SW	89	281660	664869	223.4	1300
SALTFLEETBY 1	TF49SW	50	541450	390883	7.62	*
SALTGREEN NO1 BORE	NS98NW	197	291955	686081	3.33	557
SALTOM PIT	NX91NE	3	296432	517400	*	248.72
SANDONBANK	SJ92NW	5	394716	327480	102.26	1114.65
SANDPIT	SK21NE	4	426830	318950	61.34	276.45
SANDS LONGANNET BORE NO1	NS98NE	170	295064	685750	14.37	434
SANDS ROAD BORE NO 5	NT29SE	25	328185	690985	4.88	217
SANDYCROFT 2	SJ36NW	11	333330	367490	5.18	209.25
SANKEY	SJ58NE	31	356635	389020	13.93	1126.41
SAUCHIE NO1/78 BORE	NS89SE	181	288139	694759	43.75	447
SCAFFOLD HILL, RISING SUN COLLIERY NO.10	NZ36NW	1	430325	569472	67.67	410.87
SCAFTWORTH	SK69SE	10	467610	391670	18.97	1160.15
SCALM PARK BH2	SE53SE	48	456524	432259	6.55	320
SCALM PARK BH3	SE53SE	49	456510	431530	6.67	290
SCALM PARK SURFACE BH	SE53SE	13	456413	432663	5.54	532.18
SCAMPTON 2	SK97NE		498335	378178	54.63	*

SCAMPTON WEST 1	SK97NW	31	493480	378912	10.36	1800.14
SCHOOLHOUSE	SJ93NW	54	393525	337800	232.98	952.84
SCOFTON	SK68SW		462780	380530	27.7	950.98
SCOTIA	SJ69NW	12	362900	397960	29.54	498.65
SCREVETON 1	SK74SW	1	473076	343488	25.781	*
SEA MINE,VALLEYFIELD COLLIERY	NT08NW	364	300290	686050	3	261
SEAFIELD COLL 300FTHM MINE	NT28NE	39	329000	688850	-548	738
SEAFIELD COLL. 170FTHM MINE	NT28NE	38	328305	689105	-310	405
SEAFIELD COLLIERY 170FM MINE	NT38NW	4	331463	688653	-463.67	334
SEAGRAVE BILBOROUGH	SK54SW	2	451590	342557	103.5	335.58
SEAHAM COLLIERY BOREHOLE AT EAST HOUSE FARM NEAR B	NZ35SE	191	438868	551647	106.09	*
SEALAND 1	SJ36NW	7	333280	368130	5.49	224.94
SEATON ROSS 1	SE73NE	4	477014	438593	*	1036.30
SEATON SLUICES B.H 87SE2	NZ37NW	10	432918	577350	7.9248	274.32
SEGHILL COLLIERY	NZ27SE	20	427540	574810	*	*
SERLBY 1	SK68NW	23	462974	389756	9.74	*
SHAFTON COLLIERY S7 BH	NZ43NW	7	440792	538870	*	313.03
SHATTERFORD	SO78SE	15	379010	281030	*	422.78
SHEEP LANE BH No.2	SE50SW	47	451752	403275	70.02	495.23
SHERDLEY COLLIERY SHAFT	SJ59SW	19	351910	393990	*	355.78
SHERRICLIFFE FARM	SK73SE	58	479002	330543	144.05	797.5
SHERWOOD COLL. No.1 SHAFT	#	#	453700	362470	109.42	419.81
SHIELDHALL CO-OP WORKS BORE	NS56NW	296	253285	666145	6	263
SHILBOTTLE COLLIERY 2	NU20NW	18	420961	608946	*	289.13
SHILLINGHILL 1	SE42SE	78	448504	422686	23.68	685.29
SHILLINGHILL 2	SE42SE	85	447971	423002	19.85	519.33
SHIREBROOK No.2 SHAFT	#	#	453120	366820	97.54	496.73
SHIREOAKS No.3 COLL.	#	#	455900	380900	79.25	455.12
SHOTTON COLLIERY NO. 1	NZ43NW	7	440800	538880	89.79	313.03
SHOTWICK	SJ37SW	10	333232	371908	26.55	702.19
SIDWAY MILL	SJ73NE	BJ	376030	339340	1.22	1269.54
SILVERBURN NO.17 BORE	NO30SE	56	338925	701805	18	258
SILVERHILL COLL.	SK46SE		447100	361600	164.59	395.02
SINKING BH.5	NS41SW	40	244302	614285	180	339
SKEDDOWAY BH1 STRATHORETHORNTON	NT29NE	21	325704	697575	73.46	228
SKEDDOWAY BH2	NT29NE	22	325422	697430	76.05	356
SKEDDOWAY FARM BH(2) STRATHORE	NT29NE	25	325895	697718	70.1	257
SKEDDOWAY FARM BORE STRATHORE	NT29NE	23	325920	698280	61	257
SKIERS SPRING COLL.	SK39NE	6	436400	399025	101.19	317.62
SLAGGYFORD	NY65SE		367250	551700	*	*
SLATEHOLE BORE	NS42SE	4	249070	623430	80.68	1024
SMEATHALLS BH	SE52NW	2	451380	425420	11.41	645.21
SMEEKLEY No. 3	#	#	429690	376498	190.5	287.43

SMESTOW	SO89SE	1	385549	292861	76.2	866.85
SMITHY	SJ34NW	51	332680	346940	*	320.65
SNOPE BURN	NY75SW	8	370600	554800	*	*
SNOWDOWN 2 DB	TR25SE	4	626000	150170	-802.23	155.45
SOLOMONS TEMPLE	SP28NE	63	426101	286893	*	636
SOLSGIRTH NO1/1963 BORE	NS99SE	122	297690	693133	84	414
SOLSGIRTH NO4 BORE	NS99SE	124	297165	691940	63.9	213
SOLWAY 9 U/G	NX92NE	22	297396	528880	345.95	71.63
SOLWAY COLLIERY U/G UP 5	NX92NE	5	297470	527527	*	76.81
SOLWAY SHAFT DOWN N1	NX92NE	12	299091	527693	8.41	254
SONTLEY	SJ34NW	45	333050	346090	*	366.67
SOUTH CLIFFE 1	SE83NE	8	487911	435220	10.66	*
SOUTH FOD 1	NT18NW	335	313210	687110	102	1605
SOUTH GREENS BORE	NS98NW	202	290832	687563	2.17	626
SOUTH INGS BH	SE54SE	23	458884	442642	5.81	605
SOUTH LETHAM NO.1 BORE (1952)	NS88NE	186	288620	685255	*	1094
SOUTH LEVERTON 1	SK78SE	1	479333	380411	8.31	*
SOUTH MILTON	SK77SW		470814	372295	29.32	815.5
SOUTH MUSKHAM	SK75NE	150	479348	357810	13.17	586.28
SOUTH PITKINNY FARM DIAMOND BH.	NT19NE	262	319770	696340	100	619
SOUTH SCROOBY	SK68NE	46	465277	389867	14.16	1102.28
SOUTH TYNE	NY76SW	1	370870	564550	*	*
SOUTHAM WARWICKSHIRE	SP46SW	14	442000	263340	*	965.18
SOUTHGATE (CLOWNE) COLL No.5 PIT	SK47NE	5	449328	375934	131.06	311.63
SOUTHWELL SURFACE BH.	SK65SE	10	468495	353809	64.6	978
SPALFORD	SK86NW	107	483165	369706	8.95	950.21
SPALFORD 1	SK86NW		483506	369797	9.03	*
SPANISH BATTERY TYNEMOUTH	NZ36NE	103	437390	569120	16.22	217.02
SPARK HAGG BH	SE53SE	27	458395	434196	6.41	416.74
SPITAL 1	SK99SE	41	496540	391150	44.81	*
SPRING FARM BINGHAM	SK73NW	47	470319	338040	33.03	822.15
ST ANDREWS SHORE SECTION	NO51NW	3	350660	717315	6	243
ST BEES 2A	NX91SE	144	297007	513235	79	585
ST BEES 3	NX91SE	145	295984	512967	56.67	527
ST BEES 4	NX91SE	10	294980	512670	95.52	653.18
ST BEES 5	NX91SE	2	295230	512074	98.08	603
ST HELENS COLLIERY 11	NY03SW	27	300640	532240	8.99	304.8
ST HELENS COLLIERY 13	NY03SW	52	300100	531500	7.62	303.89
ST HELENS COLLIERY 16	NY03SW	55	301940	531370	*	219.68
ST HELENS COLLIERY BH	NY03SW		299750	530650	*	274.3
ST HELENS DEEP COLLIERY UB	SJ59SW	25	353200	393600	*	319.15
ST HELENS No 3 BOREHOLE	NY03SW		300900	531900	*	213
ST MARGARETS BAY	TR34NE	8	636650	145330	59.4	1199

STABHILL	SJ83NW	10	384995	336655	179.9	1152.64
STAFFLER	NY37SW	1	332973	572267	52.2	708
STAKEFORD BRIDGE	NZ28NE	56	427490	585940	8.38	359.05
STANDHEAD MONTGOMERIE BH.	NS42NW	16	243127	626445	107	655
STANHOPE BRETBY	SK22SE	7	428060	322270	100.89	378.56
STANTON FARM	SK21NE	2	425940	319630	66.45	347.01
STAPLE & BH IN PIT A HEBBURN	NZ36NW	136	431500	565400	19.82	587.57
STAPLE IN PIT A HEBBURN COLLIERY	NZ36NW	137	431420	565420	*	375.92
STAPLEFORD MOOR	SK85NE	19	486904	357584	18.75	730.94
STAR 4A MARKINCH	NO30SW	19	332250	703065	99	658
STATHERN LODGE	SK73SW	6	474654	333262	36.88	694.21
STATHERN SOUTH	SK73SE	60	477173	330555	95.12	820.58
STATION FARM	SK73NW	46	474288	335922	26.02	690.44
STEAM BORE,LANDS OF CATTLE MOSS	NS99SE	82	299775	691644	103.5	695
STEEPLE ASTON	SP42NE	12	446870	225860	*	975
STEETLEY COLL.	#	#	455200	378480	66.14	556.55
STEPPINGSTONES BH	SE40NW	120	444626	409425	45.69	298.87
STILLINGFLEET 1	SE54SE	17	458666	441252	10.85	867.6
STILLINGFLEET 3	SE54SE	18	459880	442243	10.38	734.8
STILLINGFLEET SH 2	SE64SW	22	460422	440547	8.02	678.79
STIXWOULD 1	TF16NE	9	518840	365309	8.23	*
STOCKWELL HEATH	SK02SE	4	405610	321430	85.1	517.25
STODMARSH	TR26SW	3	621110	160050	26.5	689.76
STOKE ON TERN 1	SJ62NE	BJ	365130	326270	0.7	558.39
STONE	SK58NE	14	455559	389917	65.52	985.55
STONEFORD	SJ92SE	20	395875	321570	85.51	954.22
STONEHAUGH	NY77NE	2	378990	576190	190	601.12
STONY LOW	SJ74SE	33	379052	344290	124.34	817.36
STOW ON THE WOLD 2	SP22SW	5	420197	220742	249.5	469.39
STRADEY COLLIERY BH., LLANELLI	SN50SW	17	250160	201310	19.812	378.1
STRAFFORD MAIN	SE30SW	5	432184	404138	*	319.4
STRATA AT BLAIRENBATHIE SHAFTS	NT19NW	145	311190	695278	181.66	208
STRATHORE BORE NO1	NT29NE	28	327344	698348	53.04	469
STRATHORE NO3 BORE	NT29NE	43	327881	696834	51.79	514
STRELLEY	SK54SW	560	450516	342956	*	*
STRETTON	SJ81SE	13	387560	310200	107.72	1215.38
STRETTON 1	SK31SW	66	430580	312350	73.15	294.16
STROOM DYKE	SK73SW	9	471386	334546	22.08	691.4
SUTTON	SK68SE	1	468171	383849	13.72	1082.6
SUTTON COLL.	SK46SE		448300	360200	172.82	427.64
SUTTON MANOR COLLIERIES 1 BORE	SJ59SW	8	351820	390780	60.05	764.41
SUTTON ON TRENT 1	SK76SE	2	479950	364950	25.91	*
SWAITHE COLL.	SE30NE	4	437595	404068	48.77	210.31

SWANTON COURT	TR24SW	2	623865	144309	144.7	1263.4
SWEENEY	SJ22NE	19	328910	327440	115.82	153.57
TADMARTON 1	SP43NW	21	440660	237110	122.59	1037
TALACRE 2	SJ18NW	13	311837	385158	4.69	300.53
TALWRN 2	SJ24NE	3	328960	347710	*	296.26
TANHOUSE	SJ59SE	7	357220	392590	19.54	1200.3
TANKERSLEY COLL.	SK39NW	3	434150	398942	163.07	221.78
TEDDESLEY NCB 501	SJ91NW	16	394207	317011	*	*
TERNHILL 1	SJ63SW	BJ	363150	331320	0.69	713.53
TETNEY LOCK 1	TA30SW	5	533250	400900	5.58	2851.4
THISTLEBANK BH	NS98SW	179	291274	683926	3.09	611
THORESBY COLL No.1 SHAFT	SK66NW		463530	367610	69.49	580.9
THORNE COLL No.1 SHAFT	#	#	470665	415881	4.88	881.03
THORNEY BH	SK87SE		485221	372648	9.68	1106.52
THORNHAM ESTATE ROYTON 3	SD80NE	2	389684	409178	*	322.48
THORNTON BRIDGE BORE	NT29NE	69	328890	697221	51.18	968
THORNTON FARM BORE	NT29NE	68	329691	697500	48.78	1154
THORNTON LE CLAY 1	SE66NE	8	467366	465119	*	1154.28
THORPE HALL SURFACE BH	SE53SE	12	457771	432016	6.21	457.81
THREEPSIKES BORE	NT09SW	498	302708	694381	160.12	383
TIBSHELF OLD PIT	SK46SW		444300	360100	156.06	358.88
TICKHILL 1	SK59SE	2	457730	392970	28.85	*
TILE KILN WOOD	SK57SE	9	455425	373129	52.66	283.46
TIMBERTREE COLLIERY ROWLEY REGIS	SO98NE	33	395240	285220	126	264.61
TIMPANHECK	NY37SW	2	332207	574677	83.99	558
TODDY BRIDGE BORE	NO30SE	2	336065	703975	107	340
TOECROFT FARM SURFACE BH CRESSACRE DRIFT NO.23	SE50SW	42	452930	403200	56.09	476.36
TOFT	SJ84SW	84	384725	340369	152.36	1140.04
TOFTS FARM DOUGLAS DIAMOND BH	NS83SE	1	286155	634906	*	*
TORKSEY 1	SK87NE	2	485907	377661	7.77	*
TORKSEY 4	SK87NE		485065	379222	10.44	*
TORRANCE NO.1 BORE	NS67SW	98	264195	673590	35.6	439
TORRANCE NO.2 BORE	NS67SW	99	264085	673915	39	498
TORRIDON AVENUE BH.201 GLASGOW	NS56SE	801	255771	663750	27.3	*
TORWOOD BORE (1960)	NS88SW	206	283755	684870	68.67	641
TORWOOD NO.1 BORE	NS88SW	73	283545	684335	97.05	547
TORWORTH	SK68NW	2	464960	385600	24.54	1083.7
TOWTHORPE	SE65NW	23	461814	459075	13.2	1198.00
TREATON 3A	NO30SW	18	332630	701900	73	445
TREVALYN	SJ35NE	148	337678	357238	16.17	1353.9
TRIMSARAN (No.2) BH	SN40SW	17	244830	204160	104.55	245.78
TRUMFLEET 1	SE61SW	79	460520	412640	8.17	*
TULLIALLAN FOREST BORE NO1	NS98NE	116	296899	688151	81.29	203

TULLIBODY NO 1/78 BORE	NS89NE	99	286008	695939	16.04	328
TULLIBODY NO2 BORE	NS89SE	72	286895	693755	10.67	830
TULLYALLAN NO 1 BORE	NS98NE	7	297055	687435	61	856
TULLYALLAN NO2 BORE	NS98NW	46	293815	686825	9	867
TULLYBRECK FARM BORE	NT39NW	35	331584	698571	48.65	853
TURFMOOR	SK85NE	14	485111	358830	16.7	851
TUXFORD	SK77SW		472180	370500	78.15	1294.2
UFTON	SP36SE	20	438435	264246	66.64	1016.35
ULCEBY CROSS 1	TF47SW	16	541400	373850	100.58	*
ULLESKELF BH	SE53NW	41	452010	439183	*	307.03
ULLOCK 2	NY02SE	138	306070	523780	126.49	359.66
ULLOCK 3	NY02SE	139	306790	523110	131.06	256.03
ULLOCK 4	NY02SE	140	305720	524220	119	245.99
UNIVERSAL COLLIERY, LANCASTER PIT	ST19SW	11	311345	191211	204.22	592.84
UPTON 2	SK75SW	6	473222	352919	17.33	*
UPTON BURFORD	SP21SW	1	423150	213130	113.99	1148.18
VALE FARM CLIPSTON	SK63SW	18	462743	334754	34.15	519.38
VALLEYFIELD NO2 SHAFT	NT08NW	288	300980	686410	3	703
VALLEYFIELD NO3 SHAFT	NT08NW	281	300955	686295	6	731
VAN DYK	SK57NW	42	450058	377186	139.76	404.76
VANE TEMPEST COLLIERY, DURHAM OFFSHORE BOREHOLE NO. VT.9.	NZ55SW	4	450019	554778	-48	639.14
VAUXHALL COLLIERY 1	SJ34NW	21	330530	345370	*	468.5
VICARAGE FARM	SP41NE	40	449180	218680	76.19	605
VICARAGE LANE	SK75NE	149	478335	359832	11.19	704.54
VICTORIA COLLIERY NO.2 PIT	SD50NE	10	357679	409294	*	573.56
VICTORIA WORKS LIVERSEDGE YORKS	SE12SE	11	418366	424061	*	287.43
WALTON WOOD	#	#	420890	316641	*	*
WARDLEY COLLIERY NO2 SHAFT	NZ36SW	4	430530	561980	53.95	513.74
WARKWORTH	SP43NE		448195	239713	94.71	673.84
WARREN	SK68NE	45	467654	389850	14.67	1112
WARREN HILL	SK21NW	6	422960	318670	69.1	698.6
WARREN HOUSE	SK49NW	21	444400	397400	99.06	399.64
WARSOP COLLIERY No.1 SHAFT	#	#	454700	368100	74.68	501.61
WATERGATE COLLIERY No 2 SHAFT	NY03SW	2	303290	534220	*	216.1
WATH MAIN COLL.	SE40SW	27	443908	401930	22.86	647.13
WATNALL COLLIERY NO.1 PIT	SK54NW	37	450750	348005	115.34	312.85
WEARMOUTH COLL D PIT 4	NZ35NE	99	439190	557910	24.58	652.09
WEARMOUTH COLLIERY OFFSHORE BORE WM4A	NZ55NW	1	452404	556890	-48.4	720.02
WEBHEATH 1	SP06NW	100	400980	266930	113.1	390.75
WEETSLADE 3 SHAFT	NZ27SE	3	425160	570912	59	338
WEETSLADE COLLIERY	NZ27SE	1	425440	570360	*	*
WEETSLADE NO. 2 SHAFT	NZ27SE	5	425464	571843	65.99	385.75

WEETSLADE NO. 3 SHAFT	NZ27SE	6	425413	571867	65.61	399.59
WELBECK NO 2 SHAFT	SK57SE	1	458116	370280	65.53	655.1
WELBECK NO.1 SHAFT	SK57SE	1	458041	370274	66.57	656.89
WELFORD PARK STATION	SU47SW		440650	173610	106.07	1300.16
WELLESLEY CL NO.7(UP BH)E.DOOKS	NT39NE	45	338131	698761	-655	*
WELLESLEY COLL NO.6 BH	NT39NE	42	339629	695877	-440	*
WELLESLEY COLL.BH NO1 NO5 LEVEL	NT39NE	40	339790	696272	-395.33	343
WELLESLEY COLL.BH NO5	NT39NE	41	338355	697669	-446.23	299
WELLESLEY COLL.CROSSCUT IN MINE	NT39NE	35	336819	697707	-318.41	218
WELLESLEY COLL.DENBEATH NO1 PIT	NT39NE	25	336613	698778	6.8	496
WELLESLEY COLL.NO2 SHAFT	NT39NE	26	336641	698792	6.71	278
WELLESLEY NO.13 DOWN BORE	NT39NE	50	338865	696263	-503	*
WELLINGTON PIT WHITEHAVEN	NX91NE		296747	518268	*	*
WELLOW	SK66SE	186	467540	364870	60.96	655.11
WELLPARK BREWERY	NS66NW	248	260510	665320	*	260
WELLSGREEN NO 1/1979 BH	NT39NW	381	333421	698330	48.63	1498
WELTON 1	TF07NW	14	503612	376807	22.3	*
WENTBRIDGE BH 3	SE41NE	25	448680	417242	19.86	777.32
WERBURGH	SJ74SE	31	379790	343915	155.03	924.39
WEST BANK BH	SE62SW	25	463118	423818	6.39	924.46
WEST COALTOWN BORE	NT29NE	16	329210	699340	71.63	588
WEST GOGAR BORE	NS89NW	17	283802	695687	9.52	541
WEST MOOR	NZ27SE	11	426898	570231	50.99	509.83
WEST SLEEKBURN 72	NZ28SE	3	428480	584970	21.83	409.65
WESTCOURT FARM	TR24NW	1	624550	148150	112.47	1226.4
WESTER HILLHOUSE (NCB)	NS97SW	158	291494	670190	203	610
WESTER LOCHDRUM, DIAMOND BORE	NS87NW	21	281565	678115	97	601
WESTER SHIRVA NO.1 BORE	NS67NE	83	268650	675175	44	582
WESTERNTON COLL SOUTH PIT	NZ23SW	6	423847	531647	144.48	339.27
WESTERTON(DOLLAR) NO1 BORE	NS99NE	56	296830	697250	26.6	215
WESTFIELD EASTERN CLIFF	NT29NW	442	321820	699030	*	231
WESTFIELD IGS BOREHOLE	NT29NW	418	320660	697780	80	366
WESTFIELD OPENCAST NORTH FACE	NT29NW	440	321130	698870	87	*
WESTMINSTER	SJ35SW	12	330980	353650	155.45	309.3
WESTMINSTER COLL	SJ35SW	12	330980	353650	155.45	309.3
WESTOE COLLIERY CROWN SHAFT	NZ36NE	82	437500	566780	16.91	489.51
WESTOE COLLIERY TYNE AND WEAR OFFSHORE BOREHOLE NO W14A	NZ57SW	5	450205	573800	-54.8	566.97
WESTOE COLLIERY TYNE AND WEAR OFFSHORE BOREHOLE NO W7	NZ46NE	6	445663	566593	-42.74	679.7
WESTOE COLLIERY TYNE/WEAR OFFSHORE BOREHOLE NO W15	NZ47NE	1	448093	576216	-53.1	451.23
WESTOE SHAFT D.C	NZ36NE	4	437212	566836	34.41	334.65
WESTON	SJ71SE	BJ	377610	313613	120.3	736.54
WESTON C 1	SJ94SW	14	393610	343490	209.4	861.36

WESTON C 2	SJ94SW	15	393160	343195	201.63	207.56
WESTON C 3	SJ94SW	16	393825	344720	201.93	490.96
WESTOWN BH. 3	NS83SW	144	282605	633930	*	*
WHEATGRASS, UPTON	SK75NW	13	473660	355427	35.8	630.3
WHELDRAKE 1	SE64NE	4	467660	446082	15.94	*
WHINNEY HILL PIT	NY01NW	282	300729	515649	*	*
WHISBY 3	SK86NE	39	488439	369444	16.9	*
WHITBURN NO.1 (D.C)	NZ46SW	5	440756	563678	91.04	520.37
WHITE LEE COLLIERY BIRSTAL	SE22NW	489	421993	425167	129.54	259.99
WHITE LODGE	SK47NW	147	442100	376700	67.13	228.7
WHITEGATE WREXHAM A5/1	SJ34NW	3	334530	349850	*	941.53
WHITEHALL 1/59	NS51SE	99	256727	611718	257.1	516
WHITEHILL IND. ESTATE, BH.2 DALKEITH	NT36NE	324	335059	666748	1.05	*
WHITEHILL IND. ESTATE, BH.3 DALKEITH	NT36NE	325	335070	666764	1.05	*
WHITEMOOR	SE63NE	15	466732	435835	7.14	1112.77
WHITEMOOR 1	SE63NE	20	466469	435830	7.93	949.24
WHITTINGTON HEATH	SK10NW	3	414780	308000	*	1249.68
WHITWELL COLLIERY	SK57NW	11	453760	379100	85.34	286.11
WHITWELL ON THE HILL 1	SE76NW	8	472769	465742	70.4	*
WHITWELL WOOD	SK57NW	7	452426	378162	110.3	299.32
WIGMAN HALL	SE64NE	6	465021	445946	11.55	1136.7
WIGSLEY EAST	SK87SE	32	486626	370392	8.96	1081.2
WILLIAM PIT AT STANDISH	SD50NE	29	356510	407720	*	740.66
WILLIAMTHORPE COLL.	SK46NW		442700	366600	137.16	510.12
WILSON WOOD COAL PIT	SD67SE		368194	472080	*	*
WINDING SHAFT, HYDE LANE COLLIERY	SJ99NW	19	394291	395161	97.54	255.73
WINDYGATES 1	NO30SE	195	335101	700337	61.11	1305
WINDYGATES 1 DIVERSION	NO30SE	195	335101	700337	61.11	1180
WINGATE GRANGE LADY PIT	NZ33NE	15	439694	537214	*	264.26
WINNING PIT	SD67SE		369022	471816	*	*
WINSCALES NO. 1	NY02NW	244	302760	526630	*	225.85
WINSCALES NO. 2	NY02NW	14	302263	527723	*	245.67
WINSON HILL	SK76NW	43	471548	368826	58.35	832.06
WINWICK	SJ59SE	50	359061	392324	13.3	1186.82
WISTOW COMMON SURFACE BH	SE53SE	14	457419	433936	7.18	515.11
WITHYCOMBE FARM	SP44SW	9	443190	240170	144.02	1065
WIVERTON HALL FARM	SK73NW	89	470620	337028	32.8	634.73
WOMBWELL MAIN COLL. No.1 SHAFT	SE30SE	7	438317	402958	68.58	531.27
WOMERSLEY	SE51NW	7	454395	419730	7.38	746.46
WOOD CLOSE	SK69NE	62	465590	395830	22.54	1127
WOOD PIT 4 SHAFT	SJ59NE	24	357149	396683	48.53	449.4
WOODBOROUGH	SK64NW	9	462150	348080	60.29	803
WOODEN BECK	SK79SW	21	474480	391355	39.96	1218

WOODHORN 2	NZ28NE	7	428920	588400	28.35	270.58
WOODHORN DRAINAGE 2	NZ28NE	106	429990	587250	13.66	313.94
WOODHOUSE	SE56SE	10	458308	463229	20.41	1138.78
WOODHOUSELEES	NY37SE	1	339119	574951	54.8	1045
WOODLAND COLLIERY 29	NZ02NE	5	406430	527010	*	*
WOODLAND FARM	SK73SE	61	476875	332226	56.66	709.21
WOODLANDS	SJ48NE	24	345390	388162	10.85	505.05
WOODSIDE BH	SE50SW	45	450584	403621	93.18	775.64
WOODSIDE BH.2	NS32NE	13	237378	628282	47.3	310
WOODSIDE FARM	SJ68NE	390	367516	389866	23.33	1768.99
WOOLDEN MOSS	SJ69NE	352	369985	395356	26.49	1601
WREXHAM & ACTON COLL 1	SJ35SW	11	332860	352210	89.92	320.93
WRITHLINGTON LOWER COLLIERY	ST75NW	7	370520	155320	69.9	449.1
WYBURN HOUSE	SK54NW	24	450801	349921	134.77	268.99
WYNDHAM PIT	NY01NW	281	301367	515490	*	*
WYNNSTAY 2	SJ24SE	2	329420	343331	123.73	379.17
WYNNSTAY LODGE BH	SK63SW	20	464630	332203	88.7	533.25
WYSALL 1A	SK62NW	2	460240	327600	90.22	*
YATE NO. 1	ST68SE	11	369750	182530	*	*
YEW TREE	SO77SW	24	371710	271920	*	183.41
YEW TREE FARM	SJ36NE	53	336760	368160	9.33	1075.03
YORKSHIRE MAIN COLL.	#	#	454481	399187	40.92	833.03