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User Guide for the BGS Methane and carbon dioxide from natural sources and coal mining dataset for Great Britain

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Foreword

This report presents a description and review of the methodology developed by the British Geological Survey (BGS) to produce a digital *Methane and carbon dioxide from natural sources and coal mining* dataset for Great Britain. The method has been critically assessed and its fitness for purpose determined by J D Appleton, N J P Smith, K Royse and M Harrison.

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Summary

This report presents a description and review of the methodology developed by the British Geological Survey (BGS) to produce an assessment of the potential hazard from Methane and Carbon Dioxide from Natural Sources and Coal Mining in Great Britain. The methodology is briefly described in this report. The purpose of the user guide is to enable those licensing this dataset to have a better appreciation of how the dataset has been created and therefore a better understanding of the potential applications and limitations that the dataset may have.

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1 Introduction

Founded in 1835, the British Geological Survey (BGS) is the world's oldest national geological survey and the United Kingdom's premier centre for earth science information and expertise. The BGS provides expert services and impartial advice in all areas of geoscience. Our client base is drawn from the public and private sectors both in the UK and internationally.

BGS's innovative digital data products aim to help describe the ground surface and what is beneath the whole of Great Britain. These digital products are based on the outputs of the BGS survey and research programmes and our substantial national data holdings. This data coupled with our in-house geoscientific knowledge are combined to provide products relevant to a wide range of users in central and local government, insurance and housing industry, engineering and environmental business, and the British public.

Further information on all the digital data provided by the BGS can be found on our website at http://www.bgs.ac.uk/products/home.html or by contacting: Central Enquiries, British Geological Survey, Kingsley Dunham Centre, Keyworth, Nottingham, NG12 5GG; Direct tel. +44(0)115 936 3143; Fax. +44(0)115 9363150 ; email **enquiries@bgs.ac.uk**

2 About the Methane and Carbon Dioxide from Natural Sources and Coal Mining

2.1 BACKGROUND

Public understanding of the effect of land contamination and ground conditions on the health of the occupants, the safety of property, and the implication for the value of property is growing. Local councils are under increasing pressure from central government to provide environmental information. Information about geological and geochemical hazards is needed, in particular, the identification of areas with a potential for land contamination or ground movement.

In response to this, BGS initiated a development programme to produce data sets that identified and assessed potential geohazards threatening the human environment in Great Britain. Since 2000, the programme has generated:

- Six ground stability hazard datasets
- Superficial deposit thickness models
- Scans of onshore borehole logs for Great Britain
- Scans of geology and historic topography maps
- Ground permeability data
- Susceptibility to groundwater flooding data
- Geological indicators of past flooding data
- GIS data identifying potential radon hazard (produced in collaboration with the HPA)
- Non-coal mining hazards data
- Methane and carbon dioxide from natural sources and coal mining

2.2 WHO MIGHT REQUIRE THIS DATA?

- Local Authority Environmental Health and Building Control Departments
- Organisations providing environmental reports for property owners and developers
- Engineers, environmental consultants, and solicitors

2.3 WHAT THE DATASET SHOWS?

The METHANE AND CARBON DIOXIDE FROM NATURAL SOURCES AND COAL MINING dataset outlines the spatial distribution of areas where emissions from methane and carbon dioxide may be a hazard at the surface and in underground works.

2.4 HAZARDS ASSOCIATED WITH METHANE AND CARBON DIOXIDE

Methane (CH_4) is most commonly produced by the decomposition of organic material, such as peat or waste materials deposited in landfill sites, or formed over geological periods of time by the burial, compaction and heating of organic material, derived principally from terrestrial plants, and its conversion into carbonaceous rocks such as coal, from which methane may subsequently be released. Methane is not very toxic but can cause asphyxiation due to the displacement of oxygen. However, the greatest hazards posed by methane are those of fire or explosion. Methane forms an explosive mixture with air when the concentration is between 5 volume % (called the Lower Explosive Limit) and 15 volume % (Upper Explosive Limit), although concentrations greater than 15 volume % should not be considered safe because of the possibility of dilution to explosive levels. A flammable gas or gas mixture is potentially hazardous when it accumulates in a confined area.

Carbon dioxide (CO_2) is a toxic and asphyxiating gas which occurs in concentrations higher than in the normal atmosphere (0.03 volume %) usually as a result of oxidation of organic materials, such as coal or in landfill, the combustion of organic materials or from respiration. It may also be produced as the result of the reaction of acid waters on carbonate rocks, such as limestone. Carbon dioxide is a stimulant of the respiratory and central nervous systems at high concentrations and may produce unconsciousness and death at very high concentrations. The physiological effects depend upon the degree and nature of exposure and may appear in both the short and the long term. The long term exposure limit for carbon dioxide based on an 8 hour reference period, is 0.5 volume % whilst the short term exposure limit, based on a 10 minute reference period, is 1.5 volume %.

Oxygen deficient air is commonly found in old mine workings and tunnels and could occur in any enclosed space with high levels of carbon dioxide or methane, or in situations where oxygen has been adsorbed in acid mine water. A person entering an oxygen deficient atmosphere with only 6 to 10% oxygen will collapse within 40 seconds.

2.5 PRINCIPAL SOURCES AND OCCURRENCES OF METHANE AND CARBON DIOXIDE EMISSIONS FROM NATURAL SOURCES AND COAL MINING

In the UK, methane and carbon dioxide emissions from natural sources are associated with coal, carbonaceous shales, and peat as well as organic rich muds and silts in buried ponds, lakes or drainage channels. The majority of problems originate from coal-bearing strata and especially disused coal mines.

The relatively small number of gas emission incidents recorded in most areas of the UK suggests that the hazard is relatively minor and of local significance compared, for example, with the extensive problems associated with mining related subsidence or gas problems associated with landfill sites. However, in some parts of the Northumberland coal field, for example, a relatively high number of gas emission sites have been identified, so the gas hazard is correspondingly greater.

Whereas specific problems with methane and carbon dioxide from natural sources and coal mining can cause severe and, sometimes, expensive or dangerous problems, most gas emissions from natural sources and mining can usually be dealt with readily if they do arise.

Emissions of these gases may represent both short and long term hazards depending on the nature of the gas mixture, the geological conditions and the proximity and extent of buildings, construction operations, underground mining or tunnels (Appleton, 1995; Appleton et al., 1995; Creedy, 1988, 1989; Humphries, 2001, 2007; TSO, 1996; Young and Lawrence, 2001).

Methane and carbon dioxide are produced during the conversion of buried vegetation into coal. Much of the gas is lost but some, especially methane, is held by the coal in an adsorbed state. In the past, natural degassing of coal measures produced surface emissions of methane, for example in the Wigan area (Robinson and Grayson, 1990), but this is no longer a common occurrence. Gas is only freely released from coal either in the vicinity of geological disturbances, such as faults, or as a result of mining. The most significant actual, and potential, occurrences of surface methane and carbon dioxide emissions are in areas of shallow coal mining where there are many disused mines. The methane, and to a lesser extent carbon dioxide, that emanates from working mines due to the high rate of disturbance, is emitted under controlled conditions. Mine closure procedures are designed to reduce the risk of surface gas emissions. Although the release of methane will normally decline sharply when production stops, the release of gases will continue after the mines are closed and, if dewatering and ventilation operations are stopped, the remnant gases may accumulate in the mine workings. Migration of gases from coal mines can be influenced by changing water levels associated with mine dewatering. Seepages of gases at the surface may result if water levels are allowed to rise in a disused mine, though this would depend on the existence of a suitable natural leakage pathway, such as a fault, or artificial migration pathways (including the mine workings themselves; tunnels and shafts; blasting and subsidence fractures; and boreholes) connecting the mine workings with the surface. Conversely, the risk of surface gas emissions may be reduced by flooding as this may seal the gas in lower workings and prevent its migration to the surface. In general it is difficult to predict the severity of the methane hazard from individual mines due to the complexity of the geological and other factors involved.

A number of former mining communities have suffered from methane seeping into buildings, including Bedford Terrace in Barnsley, Mosborough in South Yorkshire, Gateshead, and Arkwright in Derbyshire where uncontrollable methane emissions were detected in houses and public buildings. The village was demolished and rebuilt at a safe location about a mile from its original site. Oxygen deficient air containing high levels of carbon dioxide (locally known as *stythe* or *blackdamp*) has caused problems in Northumberland, and led to the death of a man at Widdrington Station. Stythe is formed by the oxidation of coal, timber and minerals such as pyrite in badly ventilated coal workings, and is prone to accumulate in old pillar and stall workings (Young and Lawrence, 2001). Accumulation of methane gas thought to originate from deeply buried rocks led to the fatal explosion at Abbeystead in Lancashire (Hooker and Bannon, 1993).

Tunnel operations are particularly prone to gas problems especially where methane or carbon dioxide dissolved in groundwater is released as a result of changing pressure. Tunnels and other structures associated with dams may suffer problems with gas derived, for example, from accumulations of organic matter in the reservoir or juxtaposition of limestone and oxidising sulphide-rich rocks during construction, which may lead to the release of carbon dioxide gas.

Once released from their source, gases may migrate through rocks or unconsolidated deposits if they are permeable, or along mechanical discontinuities such as open joints, fractures, bedding and fault planes. Migration is generally upwards from the source to the surface, unless the gas is trapped at intermediate depth. Gases migrate in response to pressure, temperature, concentration gradients or density effects. Drops in barometric pressure will lead to increases of gas flow whilst groundwater changes may cause gases to migrate. Conversely, gas migration may be temporarily stopped by waterlogging or freezing of the ground. Gases may also be dissolved in groundwater and may be released as groundwater enters natural or man-made voids, or as pressure conditions change. Hydrocarbon gas and oil migrate from source rocks at depth towards the surface leading to accumulation in structural traps or, more rarely, seepages at the surface. Drilling or underground works may break into hydrocarbon traps leading to the release of gas or oil.

Methane and carbon dioxide released from rocks and unconsolidated deposits into the open air generally do not present a direct hazard. However, gas may enter buildings through cracks in floors, sewerage systems, construction joints, cavity walls, floor structures, wall claddings, ventilation ducts and gaps around service pipes entering a building, including sewers and the backfill surrounding pipes or cableways. Methane and carbon dioxide that enter and accumulate in poorly ventilated enclosed spaces such as some basements, buildings, caves, mines, and tunnels can reach high concentrations in some circumstances. Some fatalities have been reported where carbon dioxide has accumulated in trenches and at the entrances of disused mines. Gas levels in buildings and underground constructions will be influenced by the construction method and the degree of ventilation.

There is an effective and systematic strategy for monitoring and controlling methane and carbon dioxide in underground constructions and mines, but this does not apply to surface buildings and other constructions, unless there is a compelling reason to suspect high gas concentrations, for example if the site is close to a landfill site or if gas has been detected.

2.6 GAS HAZARDS AND THE PLANNING SYSTEM

BGS research (Appleton et al., 1995) recommended that the role of the planning system should be confined to the provision of information about the gas issue. This information (about the application of relevant Building Regulations, Health and Safety Legislation, etc.) should be contained in development plans and in decision letters about individual planning applications. Castle Morpeth Borough and Northumberland County Councils sometimes apply planning conditions to protect buildings from the ingress of gas from former coal mine workings, in particular Stythe (Blackdamp). These include the requirement for the incorporation of protective measures such as a heavy membrane in the development "in order to prevent any accumulation of oxygen deficient air which may potentially be prejudicial to the occupants of the premises" (Northumberland County Council, 2009).

Wardell Armstrong (TSO, 1996) suggested that "Coal Authority (CA) Consultation Areas" could be the basis for a planning response to gases from disused coal mines within current CA Consultation areas but restricted to the surface exposure of Coal Measures or shallow Coal Measures. Wardell Armstrong (TSO, 1996) also suggested that LAs could advise developers of the possible risk of gas emissions by incorporating "consultation areas and appropriate guidance into their development plans." It was recommended that mine gas consultation areas should not include the deep concealed coal field on the basis that mine gas problems are generally not encountered where coal mining is at depth, unless "deep mine shafts link the surface with underground workings" (TSO, 1996). They also suggested that "Mine gas consultation areas could, therefore, be restricted to parts of existing consultation areas." This is true for mine gas emissions, but it is clear from the BGS Natural Contamination Review (Appleton et al., 1995) that 'natural' gases are emitted from other sources, and whereas, these are apparently of lower risk and frequency, they still merit consideration. Therefore, general gas susceptibility data that indicate some of the geological factors that impact on the relative susceptibility to or potential for gas emissions would serve to provide planning authorities and developers with an indication of those areas where more detailed consideration of the potential problems should be carried out, whilst not over-emphasising the potential of encountering problems, which it is known are relatively rare in most areas.

In Planning Policy Statement 23: Planning and Pollution Control (PPS23; ODPM 2004a), Annex 2: Development of Land Affected by Contamination it states that "Potentially hazardous substances, such as ….. methane …… may also be present in the ground due to the underlying geology. Since these may pose a risk to the health or to the environment, their presence is a material planning consideration" and "LPAs should include appropriate information on both naturally-occurring and industrial contaminants in the land condition and quality section of their LDDs". PPS23 also refers to Part C of the Building Regulations in which mention is made of a BGS Report1 "which gives guidance on the geographical extent of these contaminants and associated hazards." and in para 2.41 it states that "LPAs should also examine ...... records held by the British Geological Survey"

2.7 GAS HAZARDS AND BUILDING REGULATIONS

Building Regulations, administered by Local Authority and other building control agencies, require precautions to be taken to avoid danger to health and safety caused by substances on, or in, the ground to be covered by the building (OPDM, 2004b). The Building Regulations and various other statutory regulations administered by the Health and Safety Executive adequately cover the need for precautionary measures in areas where high levels of methane and carbon dioxide have been discovered.

Emissions of methane and carbon dioxide appear to fluctuate with meteorological conditions (especially atmospheric pressure) and potentially also with subsidence or other movements in the ground which may affect migration pathways. Changes in land use and development may change patterns of gas movement and accumulation. Because of the potentially highly variable levels of methane and carbon dioxide gas flow within a particular site, detailed site investigation might not be a totally reliable method of determining gas risk. In such situations, it may be more appropriate and cost effective to require, under Building Regulations, the incorporation of protective measures in new buildings located within any area that is susceptible to 'natural' methane or carbon dioxide emissions. In areas where methane and radon hazards may coincide, such as in the vicinity of landfill sites or disused coal mines located in radon affected areas, some radon precautionary measures (i.e. electrical fans) may increase the hazard from methane.

The Building Regulations make provisions for the protection of new dwellings against the ingress of gases but apply only in respect of built structures on specific sites. Building Regulations cannot be applied to other types of development or of land use, for instance use of underground spaces, or to problems which may originate outside the boundary of, but may affect, the site in question. In view of these limitations, there may be a case for examining in more detail how such exceptions should be dealt with.

2.8 PURPOSES OF THE DATASET

As a consequence of requirements identified by Appleton et al., (1995) and TSO (1996), the BGS developed new 1:50,000 scale gas emission susceptibility data in a format suitable for use by Local Authorities and also for the provision of reports to developers, their advisers and property owners through the BGS GeoReports service and Value Added Resellers of environmental information, such as the Landmark Information Group and Groundsure. The new digital data replaces more general 1:625,000 scale maps published in 1995 (Appleton et al., 1995).

In order to inform planners, developers, and others, the methane and carbon dioxide from natural sources and coal mining dataset has been developed to indicate those areas where:

- caution should be exercised in forward planning due to the constraints that emissions of 'natural' methane and carbon dioxide, may impose on development by virtue of public health or safety implications;
- developers need to be aware that potential problems may be associated with gas emissions;
- employers at some places of work may have responsibilities under The Health and Safety at Work etc Act 1974 to monitor gas levels;
- householders, property owners and purchasers may need to be advised of the potential hazards by their advisers during property conveyancing.

The data are intended to prompt local authorities, landowners, prospective developers, property conveyancers and their advisers to consider whether there may be a need to seek further information or to consult an appropriate specialist.

The data can also be used as a 'constraints map' showing those areas potentially affected by emissions of methane and carbon dioxide from natural sources and coal mining.

Searches of the full dataset are available by postcode or by site area from the BGS enquiries service (Direct tel. +44(0)115 936 3143; Fax. +44(0)115 9363150 ; email **enquiries@bgs.ac.uk**).

The gas emission data set described in this report highlights the principal areas in Great Britain potentially susceptible to gas emissions. Additional and more comprehensive data available from the BGS includes a wider range of information which identifies areas less susceptible to gas emissions and also some of the geological features, such as permeable sandstones and faults, which may increase the likelihood of encountering gas.

3 Technical Information

The METHANE AND CARBON DIOXIDE FROM NATURAL SOURCES AND COAL MINING dataset is split into two layers:

1. METHANE AND CARBON DIOXIDE FROM BEDROCK SOURCES AND COAL MINING - BEDROCK
2. METHANE AND CARBON DIOXIDE FROM BEDROCK SOURCES - SUPERFICIAL

3.1 DEFINITIONS

- METHANE AND CARBON DIOXIDE FROM NATURAL SOURCES AND COAL MINING – BEDROCK (*Methane_Carbon_Dioxide_Bedrock.shp*) indicates the principal areas of Great Britain potentially affected by gas emissions from bedrock sources and coal mining.
- METHANE AND CARBON DIOXIDE FROM NATURAL SOURCES – SUPERFICIAL (*Methane_Carbon_Dioxide_Superficial.shp*) indicates the principal areas of Great Britain potentially affected by gas emissions from peat.

3.2 SCALE

The METHANE AND CARBON DIOXIDE FROM NATURAL SOURCES AND COAL MINING is produced for use at 1:50 000 scale.

3.3 FIELD DESCRIPTIONS

Table 1 Attribute table field descriptions for METHANE AND CARBON DIOXIDE FROM NATURAL SOURCES AND COAL MINING – BEDROCK (*Methane_Carbon_Dioxide_Bedrock.shp*)

FIELD NAME	FIELD TYPE	FIELD CONTENT
HAZARD	String	GAS
DESCRIPTIO	String	Potential gas hazard from bedrock and coal mining
VERSION	String	Methane and Carbon Dioxide from natural sources and coal mining – Bedrock. Version 1

Table 2 Attribute table field descriptions for METHANE AND CARBON DIOXIDE FROM NATURAL SOURCES AND COAL MINING – SUPERFICIAL (*Methane_Carbon_Dioxide_Superficial.shp*)

FIELD NAME	FIELD TYPE	FIELD CONTENT
HAZARD	String	GAS
DESCRIPTIO	String	Potential gas hazard from peat
VERSION	String	Methane and Carbon Dioxide from natural sources – Superficial. Version 1

3.4 CREATION OF THE DATASET

3.4.1 METHANE AND CARBON DIOXIDE FROM NATURAL SOURCES AND COAL MINING – BEDROCK

3.4.1.1 INTRODUCTION

The METHANE AND CARBON DIOXIDE FROM NATURAL SOURCES AND COAL MINING - BEDROCK dataset described in this report is derived from DiGMapGB-50 (v.3.14) and based on the spatial distributions of (a) Carboniferous bedrock units containing major coal seams and (b) Carboniferous and Jurassic bedrock units containing minor coal seams but only where there is evidence that these have been mined (i.e. where they are intersected by the ARUP (1990) coal mining dataset). The data is unioned with a 5 km OS grid.

3.4.1.2 CARBONIFEROUS BEDROCK UNITS CONTAINING MAJOR COAL SEAMS

Coal-bearing rocks occur principally in the Carboniferous and to a lesser extent in the Jurassic strata of Great Britain. The following units should be considered as having significant thicknesses of major coal seams and are classified as potentially susceptible to gas emissions at the surface and underground (Figures 1 and 2):

1. Coal Measures (throughout Great Britain)
2. Namurian Limestone Coal Formation in Scotland
3. Scremerston Coal Member (a Dinantian unit in Northumberland; called Scremerston Coal Group (SCG))
4. Pennant Sandstone Formation (specific members in S. Wales and southern England - see list below)
5. Grovesend Formation (includes some members with thin, but significant components of coal; e.g. Farrington and Radstock members in the Somerset Coalfield; Burford Coal and Witney Coal members of the subsurface Oxfordshire Coalfield; and the Cinderford Member in the Forest of Dean, which contains thick worked coals.
6. Bideford Formation (SW England).

It has been suggested that the areas potentially susceptible to gas emissions class could be defined by the package of Coal Measures strata extending from the lowest worked coal seam to the top of the Coal Measures (Steve Dumpleton, BGS, personal communication, 2004). Delineation of such a package of strata is not readily achievable using the DiGMapGB-50 data, especially since the lowest worked coal seam would be a different seam in different areas. So the whole of the Coal Measures is delineated as potentially susceptible to gas emissions.

Colin Waters (BGS, personal communication) suggested that the Coal Measures could potentially be subdivided into units with thick and commonly worked coals (high susceptibility) and units with thinner coals of moderate susceptibility (although still commonly thicker than any other unit outside of the Coal Measures). For example, some seams that are significant in N. and W. Yorkshire are not known or worked in S. Yorkshire. It would be possible to identify specific coal seams that would define the top and base of these high to moderate susceptibility units for each coalfield. However, this would require a significant input from BGS geologists for which insufficient funds were available.

Although minor coal seams occur within the Dinantian and Namurian strata of the Carboniferous and also within Jurassic strata, the overall susceptibility of these units is probably lower.

Numerous incidences of gas problems in coal mines are recorded in the literature (Strahan et al., 1920; Bromehead, 1923; Kent, 1954; Galloway, 1969; personal communication, Browne, M A E, 1991). Incidences of surface gas seepages are much less common. Historically, the South Lancashire coalfield was notable for the number of surface gas emission incidences (Robinson and Grayson, 1990), but these seepages appear to have terminated as a result of ventilation and dewatering during the development of deep mines after the 1850's. Creedy (1988) outlined the geological controls on the formation and distribution of gas in British coal measures strata. Although it is difficult to ascertain, with any degree of confidence, if certain areas underlain by Coal Measures strata are currently more or less susceptible than others to gas emissions, recent incidences (number in brackets) encountered during the BGS review published in 1995 (Appleton et al., 1995) indicated that the South Wales (10), Lancashire (8) and Yorkshire coalfields (6) are the most susceptible followed by South Midlands (4), Central Valley of Scotland (4), Derbyshire (3), Northumberland (3), and Cumbria (1). No incidences were recorded in North Wales. Since 1995 there has been significant coalfield closures, with consequent mine water rebound and increased related gas emissions.

Methane is a feature of the coal-bearing strata of the Limestone Coal Formation in the western part of Scotland (west of Grangemouth) and methane problems are known, for example at

Chryston and Hogganfield to the east of Glasgow. Methane in water has been reported from western Glasgow in the vicinity of Partick (Mike Browne, BGS, personal communication, 2004).

In the Morpeth area of Northumberland, it has been observed that carbon dioxide gas (stythe) incidents are commonly associated with the back walls of backfilled opencast sites. Open-cast working faces frequently intersect old pillar and stall workings and this may be the source of the gas, with gas migrating up the junction of the backfill (which is not particularly compacted or sealed). In the Morpeth area some stythe emission incidents are associated with open cast workings that were backfilled in the 1960's (B. Young, BGS, personal communication, 2004).

Migration of gas into overlying bedrock units is difficult to predict. Both the BGS and Wardell Armstrong studies (Appleton et al., 1995; TSO, 1996) indicated that surface emissions were frequently associated with sandstone units, especially fractured, massive sandstones. There is also the issue of variable degrees of porosity and permeability dependent on burial diagenesis of Coal Measures sandstones, which cannot be determined from existing map-based data sources such as DiGMapGB-50. Consequently, all sandstones in areas where coal-bearing strata are mapped and there is evidence of coal mining (based, for example, on the ARUP (1990) data) should be considered to have an enhanced potential for emissions of gases.

Gas emissions are not restricted to ground directly above the coal seams but are associated with all rock types including sandstones and coal-bearing mudstones as well as with areas where the Coal Measures are covered with relatively impermeable till. For example:

- methane gas at Bedford Terrace (Barnsley) and Mosborough (Sheffield) emitted at the surface through sandstones rather than through coal-bearing rocks;
- at Arkwright, in Derbyshire, methane is apparently being emitted at the surface through sandstones as well as coal-bearing mudstones;
- methane at Gateshead appears to have been emitted through sandstone, coal-bearing rocks and till;
- at two localities in Northumberland, carbon dioxide emitted through sandstone or sandstone and coal-bearing mudstone partially covered with till;
- methane gas emissions were recorded in a house in Haydock, Merseyside, which is underlain by Coal Measures covered with 30 m of till (Appleton et al., 1995);
- In Huddersfield, methane from water boreholes intersecting productive Coal Measures to Namurian strata, accumulated in buildings and caused explosions. The methane source may be coal but could also be Dinantian Craven Group shales (R. Addison, BGS, personal communication)

Wardell Armstrong (TSO, 1996) reported that:

1. Of the recorded incidents attributable to gases from disused coal mines over the past 50 years, all lie within the exposed coalfields, apart from one in Scotland (sited on the Limestone Coal Formation, which contains productive coal) and one in Lancashire. 75% of the incidents were methane and 25% stythe (CO_2 and oxygen-deficient air).

2. Case studies indicated that the major factors leading to surface incidents are: shallow disused mine workings, disused mine entries, outcropping fractured sandstones in contact with old mine workings (sandstones are a significant pathway and gas can travel considerable distances if the sandstone is fractured), and absence of impermeable superficial cover. Other factors include mine water levels, atmospheric pressure, and cessation of mine ventilation.

3. In 10% of 78 incidents studied by Wardell Armstrong, there was no definite evidence to associate gas emissions with disused underground coal mines.

4. Shallow coal seams tend to have a generally low gas content so high methane concentrations at shallow depth are probably related to: migration from deeper workings; cross-measure migration through mining-induced fractures; release of methane from an intermediate seam by mining at depth; migration of methane from gas-bearing sandstones; and/or slow desorption over a long time period (although this is not likely to lead to high gas concentrations or persistent flow).

5. 27 of 78 surface gas emission incidents were associated with shallow disused mine workings (which form a secondary reservoir permitting accumulation of gas near the surface).

6. It is not always possible to assess whether shallow workings exist because there are no records in many areas.

7. 16 incidents were related to mine closure and presumably to the cessation of ventilation. 900 collieries were closed between 1947 and 1995 but only about 75 incidents had been recorded so Wardell Armstrong (TSO, 1996) concluded that mine closure does not inevitably lead to surface gas emissions.

8. Interconnections may exist between a gas source in a deep mine and shallow mines. In one case, Wardell Armstrong (TSO, 1996) reported that gas took 6 weeks to migrate 7 km to shallow workings after ventilation ceased in the deep source mine.

9. Rising mine waters were only directly causative of surface emissions in 3 cases. In many cases of surface gas emissions, the water level was stable. Mine flooding can stop gas emission, seal off gas migration pathways, and also pressurise the flow of methane to higher levels.

10. The potential for a serious incident in a property is greater when gas migrates via shafts, as the potential rate of gas flow is much greater.

11. Mine gas hazards extending over a few streets were reported in 10 cases, the majority of which were associated with fractured sandstones. Mine gas hazards extending over a limited area of a few buildings were reported in 11 methane and 3 carbon dioxide incidents where gases probably issued from either fractured sandstone or a possibly unrecorded mine entry. The final 'extent' category was mine gas emissions related to point sources (e.g. mine gas rising to the surface via shafts or encountered when site investigation drilling)

12. 41% (26 occurrences) of all surface emissions were from disused mine entries, shafts and adits; 6% (4) probably related, 16% (10) possibly related and 37% (24) unlikely to be related to these emission pathways. 11 occurrences had insufficient data to be classified.

13. Massive fractured sandstones are both potential reservoirs and pathways but gas emissions are less likely when thick impermeable superficial deposits cover the sandstones. [Note: the extent of these sandstones can be identified using BGS 1:50,000 scale digital geological data].

14. Thick superficial clay can impede gas flow, but the presence of thick clay does not totally rule out problems (clay may be penetrated by services, for example) and one emission site at Haydock, Merseyside has 30m of till overlying bedrock.

15. In general, for surface emissions to occur the following conditions are required: (a) link to deeper mines for methane; (b) reservoir of hazardous gas within underlying workings; (c) seepage path to the surface; (d) substantial fall of barometric pressure to allow flow, or (e) rapid flooding to displace gas to surface.

16. Seepage (migration) pathways include: (a) disused mine entries with no controlled venting; (b) collapsed near-surface workings; (c) fractured sandstone overlying shallow workings or absent superficial cover; (d) backfilled quarries or opencast sites connected to underground mine workings.

Although most of the surface emissions of methane and carbon dioxide appear to be from shallow and/or historical coal or other (e.g. ironstone) mine workings in the exposed coalfields, it is considered to be inappropriate to restrict the geographical extent of the area potentially susceptible to gas emissions to mined areas because the records, especially of shallow historical mining, are incomplete. The approximate geographical extent of coal mining areas in Carboniferous strata can be obtained from maps in the Regional Reports of the Review of Mining Instability in Great Britain (ARUP, 1990), although these do not distinguish between shallow mines in exposed coalfields and deep mines in concealed coalfields.

Locations (identified by name or post-code) of areas affected by coalmines can be verified through the Coal Authority's Online Directory (www.coalminingreports.co.uk). However, it should be noted that when the Coal Authority states that in areas where no coal mining report is required (for property conveyancing) it does not mean that no coal mining strata are present. This is because the Coal Authority's mining records, for example, are not totally comprehensive, mainly due to the fact that there was no statutory obligation to produce mine plans prior to 1850. Consequently, records may be incomplete or inaccurate and additional unrecorded workings may be present. More detailed information and guidance on mined ground should be available from the Coal Authority, International Mining Consultants (IMC, who act for the Coal Authority on mine closures, demolition and restoration, especially in NE England, Yorkshire, and Notts. coalfields) and Wardell Armstrong (WA; for Lancashire, N and S Wales coalfields) from whom mine abandonment plans, mine water elevations, gas data from monitoring stations, and hydrological data may be available. Both IMC and WA would have the mining and technical expertise and experience to provide a detailed mine gas hazard assessment for a specific site. Other information pertinent to such an assessment would include information on bedrock geology, the type and thickness of superficial deposits, location of faults, mine shafts, drifts/adits, wells and deep boreholes etc. available from BGS and the Coal Authority. It is difficult to predict the severity of the gas hazard from individual mines due to the complexity of the geological and other factors involved. However, the evidence of gas incidents suggest that disused coal mines may, in certain circumstances, pose a significant hazard because gases may accumulate in unventilated mine workings.

Enhanced susceptibility to gas emissions related to migration pathways may occur especially where buildings are located on or close to (a) sandstones, especially in coal mining areas; (b) faults; (c) mine shafts and adits (comprehensive information on the location of these is currently available only from the Coal Authority); (d) permeable superficial; deposits. Major faults affecting outcropping moderately gas susceptible strata or strata buried by unconsolidated deposits are potential major migration pathways with a higher risk of surface and near-surface gas emissions. Where major Permian or Mesozoic faults affect buried strata, there is a higher risk of intersecting gas in boreholes. The likelihood of encountering gas emissions is enhanced if the site is located close to a previously recorded gas emission incident.

Reduced susceptibility may occur where gas source rocks are overlain by more than 5 m of superficial deposits and where gas source rocks are overlain by impermeable superficial deposits.

3.4.1.3 Bedrock units containing minor coal seams where there is evidence that the coal seams have been mined

Some rock formations contain coal as a subordinate but significant component. These have generally low susceptibility to gas emissions but with sub-areas which may be susceptible to gas emissions at the surface and underground. The bedrocks may be a source of coal gases (methane and carbon dioxide), as well as hydrocarbon gas and oil.

The following are included in the dataset only where there is evidence that coal seams have been mined (ARUP, 1990)

Carboniferous bedrock – Dinantian

The most significant presence of coal seams within strata of Dinantian stage (Heckle and Clayton, 2006; Waters et al., 2009) is within the Yoredale Group, which has relatively thin limestones and is not included within the Carboniferous Limestone Supergroup. The Yoredale Group (principally Tyne Limestone and Alston Formations) contains coal seams, together with hydrocarbon gas and oil source and reservoir rocks. However, the coal seams are typically thin and a relatively minor component of the total thickness.

It is not easy to subdivide the Yoredale Group into sections that contain some thick coals from those that contain mainly thin coals. The Stainmore Formation (Yoredale Group) has mainly thin coals, but as this unit is less commonly subdivided on maps it is impractical to identify parts of the succession in which coals are more abundant using DiGMapGB-50 data.

Some of the thin Yoredale coal seams have been mined in small workings in Cumbria, Durham, and Northumberland. The coal seams are too small to identify using DiGMapGB-50 data, but the approximate geographical extent of coal mining areas in the Yoredale Group can be obtained from maps in the Regional Reports of the Review of Mining Instability in Great Britain (ARUP, 1990). Whereas there is a potential gas hazard associated with these strata, the BGS is not aware of any recent incidences where surface or near-surface gas emissions have been encountered that are considered to have emanated from worked coal seams in Yoredale Group strata.

The West Lothian Oil-Shale Formation of the Strathclyde Group in the Midland Valley of Scotland contains both coals (such as the Houston Coal in the Lothians area) as well as oil source and reservoir rocks (Carruthers, 1912; Carruthers et al., 1927). Strathclyde Group strata east of Glasgow contain oil-shales of variable thickness, generally thin coals (including the Back and Fore Coals in the Sandy Craig Formation in E. Fife) and are also possible sources of gas and oil (Mike Browne, BGS pers. comm.). The distribution of oil-shale resources is well known for the West Lothian Oil-shale Formation (Sandy Craig Formation in south Fife at Burntisland). Both gas and oil occur in the basal Clackmannan Group Lower Limestone Formation in mid- to south Fife. The Anstruther Formation (Strathclyde Group) in east Fife was trialled for oil-shale and Total Organic Carbon contents greater than 20% are known from outcrops of this and other Dinantian formations. The Cousland area of Midlothian/East Lothian was a gas producing area for a number of years. Methane (firedamp) was recorded from the oil-shale mines in the Lothians and Fife (Carruthers et al., 1927).

In Scotland there are also significant worked coal seams in the Lower Limestone Formation (e.g. Hurlet and North Greens coals), the Upper Limestone Formation (e.g. Upper Hirst Coal) and also, in some parts of Scotland, in the Passage Formation.

Carboniferous bedrock – Namurian

The Millstone Grit Group contains coal seams, together with hydrocarbon gas and oil source and reservoir rocks. For example in the Millstone Grit Group, the Pendleton and Silsden Formations have rare coals in the northern part of the Pennine Basin (e.g. Sheet 69); the upper part of the Hebden Formation has rare coals across the northern and central parts of the Pennine Basin; whereas the Marsden and Rossendale Formations have thin, though locally workable seams, across much of the basin.

It is not practical to identify sedimentary formations within the Namurian that have greater or lesser numbers and thicknesses of coal seams.

Carboniferous bedrock – Westphalian

Westphalian strata with a significant number of coal seams but less than in the Coal Measures include principally the Etruria Formation, the Halesowen Formation, and the Hanchurch Sandstone of Warwickshire Group

The Publow Member of the Grovesend Formation in Somerset is included because it is reported to contain fewer coal seams than the remainder of the Grovesend Formation (see 3.4.1.2 above).

Jurassic bedrock

Coal-bearing rocks occur within Middle Jurassic strata in north east Yorkshire and Sutherland (Brora area).

Coals, which have been worked in the past, occur in the non-marine formations of the Ravenscar Group of NE Yorkshire, including the Saltwick Formation, Saltwick and Cloughton Formation (undifferentiated), Cloughton Formation and Scalby Formation (Andy Howard, BGS, pers. comm. 27 Sept 2004). The BGS is not aware of any records of gas emissions at the surface derived from these coal seams.

At Brora in the Highland Region of Scotland, Middle Jurassic strata contain coal seams associated with highly carbonaceous shales. The thin coals and bituminous shales (up to 26% TOC reported) constitute a potential gas source, though the bituminous section is only about 30m thick, and quite low in the succession exposed. The Brora Shale Formation and Clynkirkton Formation are included in the dataset where there is evidence that coal seams have been mined (ARUP, 1990), although no records of recent gas emissions have been encountered (P Stone, BGS, pers. comm., November 2004).

Jurassic units with minor coal seams in the Wealden Basin of Sussex-Kent are mainly Valanganian in age. Gas seepages in the Wealden Basin may originate from Carboniferous sediments (Taylor, 1986) or from Lias black shales.

3.4.1.4 Carboniferous bedrock gas source rocks not included in the bedrock dataset

One of the main sources of hydrocarbon gases in northern and central England are the pro-delta shales of the Craven Group. This group ranges from Dinantian to Namurian age, occurring between the Carboniferous Limestone Supergroup and the Millstone Grit Group. Within the Millstone Grit Group much of the methane is probably sourced from the underlying Craven Group rather than the thin and laterally impersistent coal seams that occur in the Millstone Grit. The delta-top sandstones more typical of the Millstone Grit may act as suitable hydrocarbon reservoirs. In contrast, the low porosity mudstone-wackestone successions of the Craven Group provide relatively few suitable reservoirs. As a source-rock, certain organic formations of the Craven Group (such as the Bowland Shale Fm.) could be considered to be potentially susceptible to gas emissions, but since they are probably a lesser hazard than the productive coal seams, they have been not been included in the dataset.

Whereas the Craven Group and Millstone Grit are the principal hydrocarbon gas source rocks in northern Britain, few incidences of hydrocarbon gas emissions were encountered during the BGS review (Appleton et al., 1995). However, the important incursion of methane gas into a tunnel intersecting Millstone Grit Group strata at Abbeystead, probably originated from thermally matured Dinantian shales of the Craven Group (Lawrence et al., 1987; Hooker and Bannon, 1993).

Historical seepages of methane derived from Carboniferous black carbonaceous shales or bituminous shales in the lead mines of the Derbyshire Peak District resulted in several fatal explosions.

3.4.2 METHANE AND CARBON DIOXIDE FROM NATURAL SOURCES – SUPERFICIAL

3.4.2.1 Introduction

The METHANE AND CARBON DIOXIDE FROM NATURAL SOURCES - SUPERFICIAL dataset described in this report is derived from the BGS DiGMapGB-50 (v.3.14) peat data. The data is unioned with a 5 km OS grid. The data set does not include other superficial geology units which may contain organic material as a subsidiary component (see section 3.4.2.3 for further detail).

3.4.2.2 SUPERFICIAL UNITS CONTAINING PEAT

Peat

Methane, and to a lesser extent carbon dioxide, is produced from peat and organic matter in wetlands under anaerobic conditions (i.e. when it is water saturated) whereas carbon dioxide is generally produced under oxidising conditions. Abundant methane and carbon dioxide is a characteristic feature of the anaerobic conditions that pertain in all peat-lands (Svensson and Rosswall, 1984; Williams and Crawford, 1984; Shotyk, 1988). Estimated total annual methane fluxes from Scottish peat bogs are reported to be 10-20 g m^{-2} though this is reduced as the temperature and water level fall. CH_4 emission includes production from fresh organic matter, methane oxidation in the soil, and transport by diffusion, through plant roots and bubbles. CH_4 production during high water table periods is suppressed by aerobic decomposition of fresh organic matter reservoirs during low water table periods. In a winter-high, summer-low water table regime, CH_4 flux peaks occur in spring and autumn but high CH_4 emission only occurs after a considerable rise of the water table.

Each square metre of modern peat land is reported to generate up to 195 milligrams of methane per day. Although this appears to be a small amount, the extensive bogs throughout the Siberian lowlands, for example, could together add 14 million tonnes of the CH_4 to the atmosphere each year. When the bogs first accumulated material, their rates of methane production may have been up to six times today's rate because plant species typical of shallow juvenile bogs produce the gas more efficiently than plants at the surface of older bogs (Smith et al., 2004)

Warmer temperatures in Siberia, coupled with melting permafrost and a lowered water table, could eventually lead to aerobic decomposition due to peat-land drying and increased soil oxygen levels. As a result, carbon dioxide would be produced instead of methane. Smith et al. (2004) calculated that the long-term benefits of lower levels of methane (which has a shorter lifetime in the atmosphere) could be significantly outweighed by the increase in carbon dioxide, leading to a positive warming impact to the atmosphere.

Drainage, vegetation removal and harvesting, and vegetation restoration have a profound effect on carbon cycling in peatlands. In general, drained peatlands are a source of CO_2, whereas if reflooding raises the groundwater level, these areas will again produce CH_4. Glatzel et al. (2004) demonstrated that "CO_2 production rates ranged from 0.04 to 1.05 mg $g^{-1}d^{-1}$ under aerobic conditions and 0.01 to 0.29 mg $g^{-1}d^{-1}$ under anaerobic conditions. Rates of CO_2 production were generally smallest in the lower parts of the profiles and at the recently restored sites where deep peat was exposed at the surface; they were largest in the freshly-formed surface peat at the undisturbed bog and older restoration sites where a strong cover of vegetation had developed. Largest rates of anaerobic CH_4 production occurred in samples close to the soil surface with fresh peat accumulation and a high water table, and smallest rates were in samples from the subsurface of sites with a low water table. Anaerobic CH_4 production was significantly positively correlated with aerobic and anaerobic CO_2 production. These production potentials show that drainage, harvesting, and restoration change the ability of the peat profile to produce and emit CO_2 and CH_4." In the UK there are numerous examples of aerobic (oxidizing) peat bodies especially those which have been or are being dewatered by drainage schemes e.g. Holme Fen.

In Great Britain, recent gas seepages have been recorded from peat and organic matter in old water courses, stream beds, reservoir sites, and tidal river sediments. Although the risk of gas seepages from upland peat is probably not very significant for planning and development because few habitable buildings are constructed on upland peat, a potential gas hazard does exist. Therefore, all types of peat, irrespective of altitude, but including both river-valley Fenland peat and upland peat, are mapped as potentially susceptible to gas emissions. In Northern and Highland Britain there are remnant kettle holes and pingoes infilled with peat but the peat is not necessarily identified by DiGMapGB-50 data.

The following DiGMapGB-50 peat bearing units, selected on the “ROCK” code, are classified as potentially susceptible to gas emissions because peat is the major constituent:

- PEAT
- POCM (peat and organic mud)
- PTSC (peat, silt and clay)
- PTSI (peat and silt).

The extent of these units is illustrated in Figure 2.

It should be noted that few dwellings are built on peat due to other problems, including compressibility and the fact that peat land is not a particularly attractive environment for human habitation. Development is more likely to occur on buried organic material in alluvium, reclaimed tidal deposits, dock deposits etc. (detailed in section 3.4.2.3 below) than on mapped peat deposits.

3.4.2.3 Superficial units which may contain organic material but which are not included in the METHANE AND CARBON DIOXIDE FROM NATURAL SOURCES – SUPERFICIAL dataset

Introduction

Organic matter and peat is generally likely to be under-represented in DiGMapGB-50 attributions because there are so few ROCK codes available that include peat as a minor constituent (actually only ALV-CZPS), and it is not possible to add an 'organic' qualifier into a code. For example most alluvium is coded as SSCL (sand-silt-clay) even though it may locally contain peat. In addition, DiGMapGB-50 generally only identifies peat deposits at the surface. It should be noted that it is not practical to identify smaller organic rich deposits, such as buried water courses and ponds, using DiGMapGB-50 data.

Alluvium

All alluvial tracts may contain peat, irrespective of their width. The wider tracts commonly have networks of abandoned channels, ox-bows, chute channels, and flood basins, all with potential for accumulating peat. Methane could be produced from buried deposits of water saturated peat and organic material in alluvial deposits and, in general, its presence should be considered on a site specific basis.

In general the likelihood of encountering peat appears to be related more to the maturity of the river system and the presence of abandoned meanders. The gradient of river systems may also give some indication of the likelihood of encountering peat, though this needs to be tested against site investigation borehole information. Some areas of peaty alluvium (ALV-CZPS; clay, silty, peaty, sandy) have been coded by some geologists in some areas, such as the lower Thames basin. However, coding discrepancies occur at map boundaries. For example, alluvium on map sheet 288 is coded as peaty alluvium but as ‘normal’ alluvium on the adjacent BGS 1:50,000 scale map sheets (287, 289, and 304) even though the descriptions in the memoirs do not indicate a perceptible difference between the characteristics of the alluvium in the four BGS geological map sheets:

- Map 287: the [alluvial] deposits are mainly soft clay, mud and silt, with a variable content of impure sand and stony loams. Peat occurs locally ...

- Map 288: The alluvium of most streams is heavy clay, but beds of peat are included locally... Peat deposits of insufficient thickness to be show on the one-inch map formed near springs ...
- Map 289: Peat occurs in the alluvial tracts of some streams and also at springs ... it is an important element of the deposits of Romney Marsh
- Map 304: no peat is reported in the alluvium within the part of the Medway catchment in this district. The alluvium of the River Rother and its tributaries is chiefly a grey silty loam or clay ... downstream .. traces of peat horizons have been discovered.

Consequently, BGS geologists consider that, in general, it is likely that peat within alluvium is under-reported.

Alluvium and Alluvium-Raised Terrace Deposits are used for the same mapped unit on adjacent map sheets, so both are grouped as Alluvium for the purposes of gas susceptibility.

Peat is present in valleys of the Calder, Aire, Wharfe and other rivers although Floodplain Alluvium of most rivers in Scotland, the Pennines and Cumbrian Mountains is unlikely to contain substantial beds of peat, unlike in Southern Britain. However, peat has been identified in former oxbows within meandering stretches of rivers in Scotland. Such stretches are few and far between, but could be delineated in some areas if resources were available. Similarly, peat occurs locally within the alluvium of enclosed basins, and within kettle holes, neither of which are identifiable using DiGMapGB-50 data.

Estuarine sediments

Estuarine sediments may be organic-rich and include a number of freshwater peat layers. These can be thick and extensive, for example in Broadland, Fenland, the Thames estuary, and the Somerset Levels.

Lacustrine deposits

Lacustrine deposits, such as lacustrine alluvium, are likely to contain organic material and in some cases peat layers, even though these units tend to be coded SSCL. However, lacustrine deposits (especially present-day lake deposits) are not always mapped. Jon Merritt (BGS) observes that Lacustrine Alluvium is likely to be organic rich. Where remnant lacustrine deposits are mapped, this was probably on the basis that they contained laminated silts and clays rather than organic layers.

The lake formation process may go through open water - enclosed water - mire - dried up/drained ground - ploughed ground, so there will be areas where former lakes have not been mapped and it was has been reported that one may exist on Holderness.

Saltmarsh deposits

Saltmarsh and Reclaimed Saltmarsh deposits contain much organic matter together with beds of peat.

Tidal flat, Raised Tidal Flat, Intertidal, & Raised Marine deposits

Tidal flat deposits, Raised Tidal Flat deposits, Intertidal, and Raised Marine Deposits may all contain peat layers or other organic material. Tidal Flat deposits are likely to be organic and peat occurs locally below some Raised Tidal Flat deposits. For example, peat occurs locally beneath Raised Tidal Flat Deposits of Flandrian Age (or Raised Beach and Estuarine Alluvium on older maps), such as the Carse clays of the Scottish Firths. In some areas, Raised Tidal Flat Deposits change into Raised Marine Deposits at sheet boundaries (e.g. Falkirk area; Morecambe area). Raised Marine Deposits are not reported to contain peat or organic material by BGS geologists.

Whereas there is evidence of submerged sediment degassing in offshore environments, there is some uncertainty regarding how likely Tidal Flats and Saltmarsh areas are prone to developing peats. Disseminated organic material will occur in these sediments, but in saltmarsh deposits, organic material tends to get washed away as a result of tidal inundation by the sea. Discrete peat beds may occur beneath both Tidal Flat and Saltmarsh deposits, these will have formed by freshwater processes, and there is no certainty that peat deposits will always lie below these particular units.

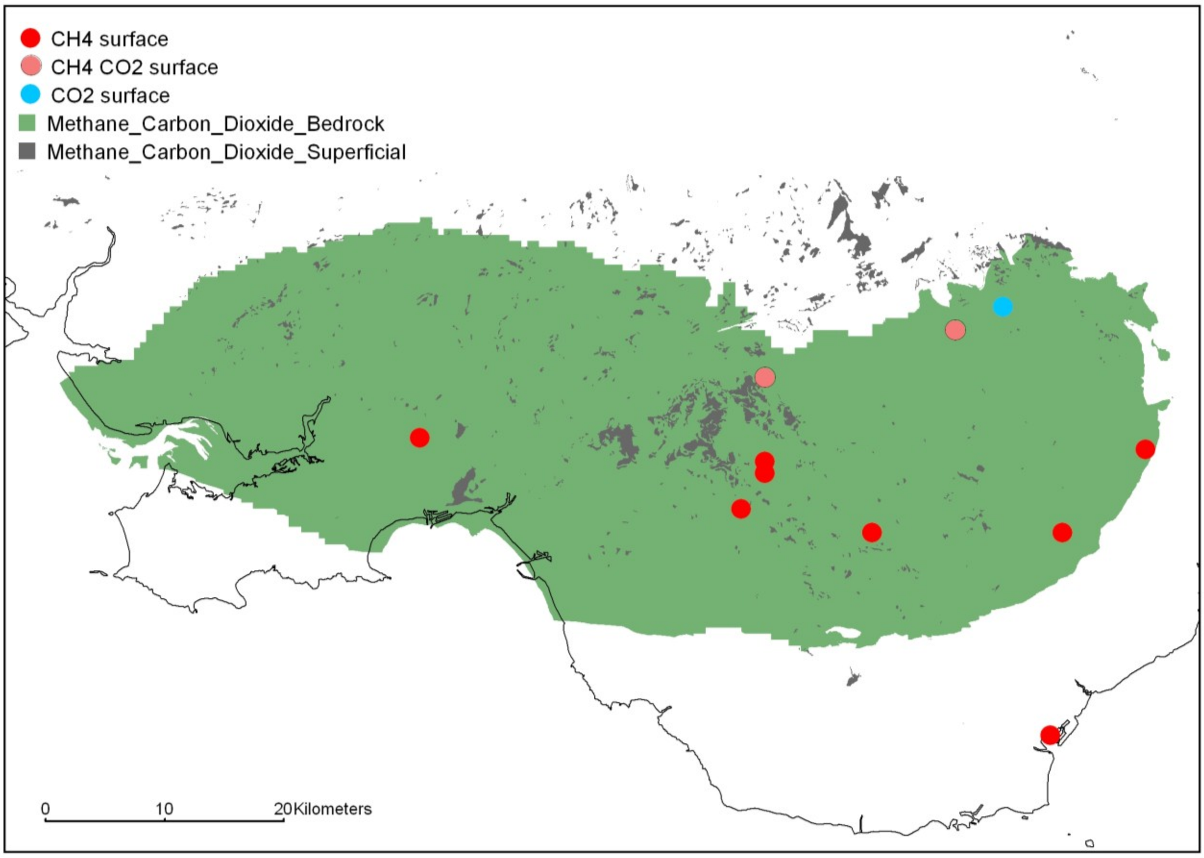

Figure 1 Extract from METHANE AND CARBON DIOXIDE FROM NATURAL SOURCES AND COAL MINING dataset for south Wales showing historical surface gas emission locations from Appleton et al., (1995).

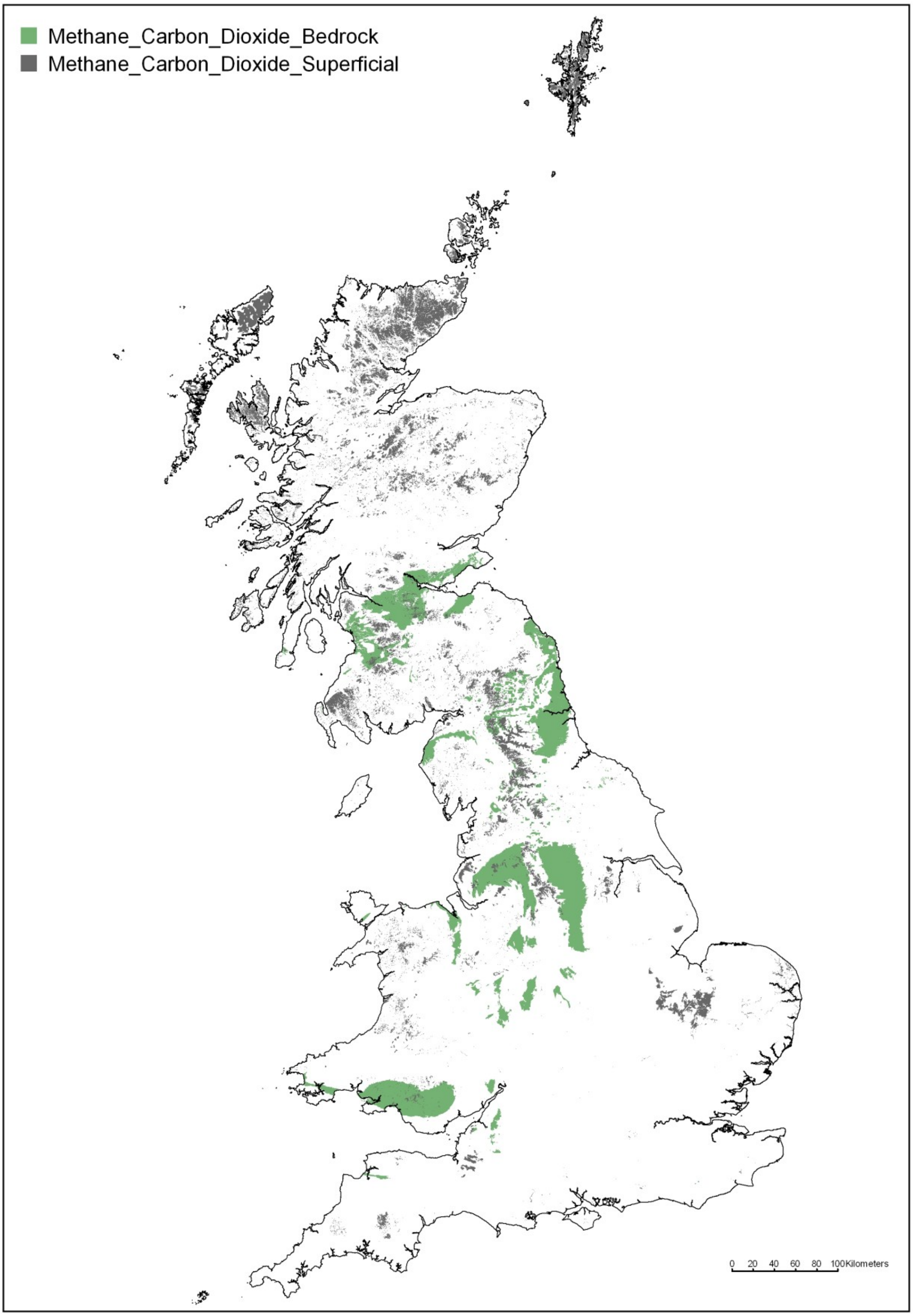

Figure 2 Methane and carbon dioxide from natural sources and coal mining

3.5 USE OF OS ADDRESSPOINT TO SEARCH THE DATASET FOR SMALL BUILDINGS IN GREAT BRITAIN

The Ordnance Survey (OS) AddressPoint dataset can be used to query the dataset. When carrying out the search, a 50m buffer should be used to allow for the spatial accuracy of the data, <u>in addition to</u> any site search radius/polygon. Together these will form the total search area referred to below. This total search area should then be intersected with the methane and carbon dioxide bedrock and superficial datasets, selecting the highest value encountered for each element.

3.6 SEARCHING THE DATASET FOR LARGE BUILDINGS OR SITES IN GREAT BRITAIN

When making spatial searches against the dataset for larger buildings, a polygon defining the spatial extent of the building (and extensions) should be used as the search area instead of the Ordnance Survey (OS) AddressPoint coordinates. The highest value encountered in the search area and 50 m buffer should be used for the overall result. The same procedure should be followed when using any other site outlines, such as for a building development site or for areas that include a number of buildings.

3.7 DATASET HISTORY

This dataset for Great Britain is based on an interpretation of the BGS digital geology and the ARUP (1990) mining instability data. The product was derived from DiGMapGB-50 V3.14 (2006) bedrock and superficial data sets. Each data layer is rectified to align with British National Grid origin.

The geological data are primarily derived from the 1:50 000 scale digital geological map of Great Britain, DiGMapGB-50. There are some areas of 1:250 000 scale geological data, for example, in upland areas of Wales and Scotland, where larger scale data are not available. BGS is continually surveying and resurveying areas of Britain, improving and updating the geological maps.

Derivation of the dataset started as part of the DOE research projects (Appleton et al., 1995), continued as part of the BGS GeoHazarD programme and is currently under the Derived Products Team of the Information Products science area.

The BGS is committed to improving the dataset as more information becomes available.

3.8 COVERAGE

Data is for Great Britain (the dataset does not include the Isle of Man).

3.9 DATA FORMAT

The METHANE AND CARBON DIOXIDE FROM NATURAL SOURCES AND COAL MINING consists of vector polygons and is available in a range of GIS formats, including ArcGIS (.shp), and MapInfo (.tab). More specialised formats may be available but may incur additional processing costs. Due to the differences in precision of different formats and to small changes in precision during translation between formats, the absolute position of features in different GIS systems may vary by a few millimetres on the ground.

Important note regarding GIS format conversion: It is strongly recommended that the data is used in the format supplied and not converted to other GIS formats as errors can be cumulative. These issues of precision may appear to be minor but can lead to different answers being reported by different GIS software solutions.

3.10 LIMITATIONS

1. The data indicate areas which include land that may be affected by surface gas emissions and also those areas where there is a possibility of accidentally encountering or intersecting gas below the surface in underground works including mines, tunnels, and shafts and when drilling. The categorisation of ground underlain by a group of rocks or unconsolidated deposits as being susceptible to methane and carbon dioxide emissions does not imply that there is any problem. That would depend on the (1) quantity of gases in the source rocks or unconsolidated deposits, (2) whether they have been released, for example, by coal mining, and (3) whether pathways and locations for accumulation occur and (4) the thickness and permeability of overlying bedrock units and superficial deposits.
2. The data provide general indications of methane and carbon dioxide susceptibility and must not be relied upon as a source of detailed information about specific areas, or as a substitute for site investigations or ground surveys. Data users must satisfy themselves, by seeking appropriate professional advice and commissioning ground surveys or site investigations if necessary, that ground conditions are suitable for any particular land use or development, or the extent of any treatment or requirement for preventive measures prior to development. The existence of gas emissions at specific sites can only be established by detailed site investigation. An assessment of hazards and risks can be achieved by desk studies and site investigations similar to those recommended for evaluating the hazard and risk of gases from disused coal mines (TSO, 1996, p. 104-126). Some of these investigations are also appropriate for gases from other sources (see O'Riordan and Milloy, 1995). Each site needs to be considered separately due to the wide variety of data and factors involved. In any case there will always be uncertainty due to incomplete records of shallow mine workings and mine entries (TSO, 1996). The level of risk from methane or carbon dioxide in a particular building or underground cavity can only be established from monitoring the spaces in which it may accumulate.
3. The data are not comprehensive and their quality is variable. Localised or anomalous features may not be represented, and any boundaries shown are approximate. Small areas of lower or higher susceptibility to gas emissions are likely to occur within areas given a specified classification because of the occurrence of small units of contrasting lithology and permeability or unmapped shear and fracture zones and underground cavities such as mine shafts and old workings. The scale of the digital data precludes the identification of such areas or features. The data are based on an interpretation of information available to December 2004. More precise and detailed information on the distribution of susceptible geological units and potential migration paths, such as faults, is available on larger scale (1:10,000 and 1:10,560) BGS maps and in BGS reports, which should be consulted if more detail is required.

4. It is important to stress that the indication of the potential for gas emissions does not indicate that there is a problem. The small number of gas emission incidents recorded in most areas of the UK suggests that the hazard is relatively minor and of local significance compared, for example, with the extensive problems associated with mining related subsidence or gas problems associated with landfill sites. However, in some parts of the Northumberland coal field, for example, a relatively high number of gas emission sites have been identified, so the gas hazard is correspondingly greater. Whereas specific problems with methane and carbon dioxide from natural sources and mining can cause severe and, sometimes, expensive or dangerous problems, most gas emissions from natural sources and mining can usually be dealt with readily if they do arise.
5. All address searches against the data should be made using Ordnance Survey ADDRESS-POINT® coordinates (under the Terms & Conditions described by the Ordnance Survey) rounded to 1 metre.
6. Address searches against the data should take into account the positional accuracy flags within the ADDRESS-POINT® database, and users are recommended to seek alternative location methods for inaccurately located addresses.
7. The following scenarios for gas emissions are not included in the dataset described in this report:
   - (i) Where Carboniferous rocks are overlain by younger strata there may be a risk of encountering gas in boreholes, underground mining or tunnels intersecting buried (concealed) Carboniferous, Jurassic or younger strata because these are the major hydrocarbon gas and oil source and reservoir rocks in Great Britain. The risk is likely to be higher in certain structural settings such as structural highs at shallow depth and near faults that intersect Carboniferous strata. In the concealed coalfields, the gas hazard is probably greatest where redevelopment takes place above and adjacent to disused, imperfectly sealed shafts.
   - (ii) Superficial deposits in which peat is a relatively minor but potentially significant component may be susceptible to gas emissions in some situations.
   - (iii) In certain circumstances, carbon dioxide problems may be associated with carbonate bedrocks that occur at or close to the surface, especially if these come into contact with sulphide rich rocks.
   - (iv) Spoil from coal and sulphide mines has some potential for gas emissions.

4 Model Questions and Answers

This section provides recommended wording for site reports associated with the use of the METHANE AND CARBON DIOXIDE FROM NATURAL SOURCES AND COAL MINING dataset.

The METHANE AND CARBON DIOXIDE FROM NATURAL SOURCES AND COAL MINING dataset is delivered as two layers: one for representing the potential for methane and carbon dioxide seepages from bedrock geology and coal mining, and one for superficial geology. Peat and organic material in buried watercourses, ponds, docks and reservoirs and tidal river sediments are not identified by this dataset. Both datasets should be queried.

QUESTION:

Is the property in an area that may be affected by methane and other gases from natural sources and coal mining?

BEDROCK LAYER: ANSWERS AND GUIDANCE:

If the location (with search buffer) intersects a polygon in the bedrock layer (a 'positive' response), then answers to the above question should be formatted:

The British Geological Survey has assessed the area of search as being potentially susceptible to emissions of methane and other gases from natural bedrock sources and coal mining. This is because the search area is underlain by rocks that contain major and/or minor coal seams at the surface or buried beneath superficial deposits, which the available evidence suggests may have been mined.

This result does not necessarily indicate that there is a problem. The small number of gas emission incidents recorded in most areas of the UK suggests that the hazard is relatively minor and of local significance compared, for example, with the relatively extensive problems associated with mining related subsidence and gas problems associated with landfill sites. Most gas emissions from natural sources and mining can usually be dealt with readily if they do arise. If a coal mining search from the Coal Authority has been recommended, this will indicate whether any shafts or adits, which may act as pathways for gas, are located within 20 m of the boundary of the property. Where the Coal Authority is aware that the property, being the subject of this search, has been affected by mine gas, this information will be included in the Coal Mining Search Report. Seek further guidance from the BGS if a coal mining search has not been recommended.

If the query (with search buffer) fails to intersect a polygon in the bedrock dataset (a 'negative' response), then answers to the above question should be formatted:

The British Geological Survey has assessed that it is relatively unlikely that the area of search is susceptible to emissions of methane and other gases derived from rocks in the ground or coal mining.

SUPERFICIAL GEOLOGY LAYER: ANSWERS AND GUIDANCE

If the location (with search buffer) intersects a polygon in the superficial geology layer (a 'positive' response), then answers to the above question should be formatted:

The British Geological Survey has assessed the area of search as being underlain by superficial deposits in which peat is a major component and therefore potentially susceptible to emissions of methane and other gases.

If the query (with search buffer) fails to intersect a polygon in the superficial dataset (a 'negative' response), then answers to the above question should be formatted:

The British Geological Survey has assessed that it is relatively unlikely that the area of search is susceptible to emissions of methane and other gases derived from superficial deposits in the ground.

ADDITIONAL GUIDANCE:

The BGS 1:50,000 scale METHANE AND CARBON DIOXIDE FROM NATURAL SOURCES AND COAL MINING dataset described in this report serves to 'flag' up the need for further consideration of potential gas problems and the need for obtaining further information from sources such as the Coal Authority, Local Authority Environmental Health Departments etc.

Developers or their advisers may need to make a site specific risk assessment following guidance such as that outlined in "Risk assessment for methane and other gases from the ground" (O'Riordan and Milloy, 1995) or "Guidance on methane and carbon dioxide" (Boyle and Witherington, 2007).

The METHANE AND CARBON DIOXIDE FROM NATURAL SOURCES AND COAL MINING dataset can be used to inform planners and developers where caution should be exercised in forward planning; where developers need to be aware that potential problems may be associated with gas emissions and oil seeps; and whether there may be a need to consult an appropriate specialist or to seek further information through desk studies and/or site investigations.

Because of the very complex nature and variability of surface methane emissions, even detailed site investigations may never be able to conclusively evaluate potential gas risk on any site proposed for development.

Wardell Armstrong (TSO, 1996) suggested that statutory consultation with the CA, which currently incorporates mining instability issues, should be improved to include information on mine gases where appropriate. Currently the purpose of the CON29M report is to indicate the impact of coal mining on stability of land and the CA is only obliged to volunteer information on a gas escape risk where the CA can be shown to have knowledge of a previously reported escape at or near the property (TSO, 1996, p.80).

A CA Residential Property Search report includes information on past, present, and future underground coal mining and also indicates whether shafts, adits, and other entries to mine workings occur within 20m of the boundary of the property. This information is important because of the important role of shafts and adits in surface mine gas problems. However, whereas the information that shafts and adits are located within 20m of the property may be useful for subsidence assessment (which is the main purpose of this information in the CA Residential Property Search), the existence of a capped mine shaft or adit at distances greater than 20m from a property could lead to a gas hazard if, for example, the property was sited on a permeable sandstone that provided a pathway for the migration of gas from the capped shaft into the building. Consequently, it would be useful to know the distance to the nearest shaft/adit as this would tell the developer (or the developer's professional adviser) whether they need to obtain more detailed information on the location of shafts/adits from the CA when carrying out a desk study of the potential gas hazard.

5 Contacts

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- provide a bureau service for others or incorporate the data in the generation of products or services for commercial purposes
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When the BGS digital datasets are revised any upgrades will be automatically supplied to the licensee, at no additional cost. The METHANE AND CARBON DIOXIDE FROM NATURAL SOURCES AND COAL MINING dataset is revised on a periodic rather than on an annual basis, licensees will therefore not automatically receive a new dataset each year unless changes have been made to the data.

These are general comments for guidance only. A licensee of BGS's digital data is provided with full details of the basis on which individual BGS datasets licensed to them are supplied.

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