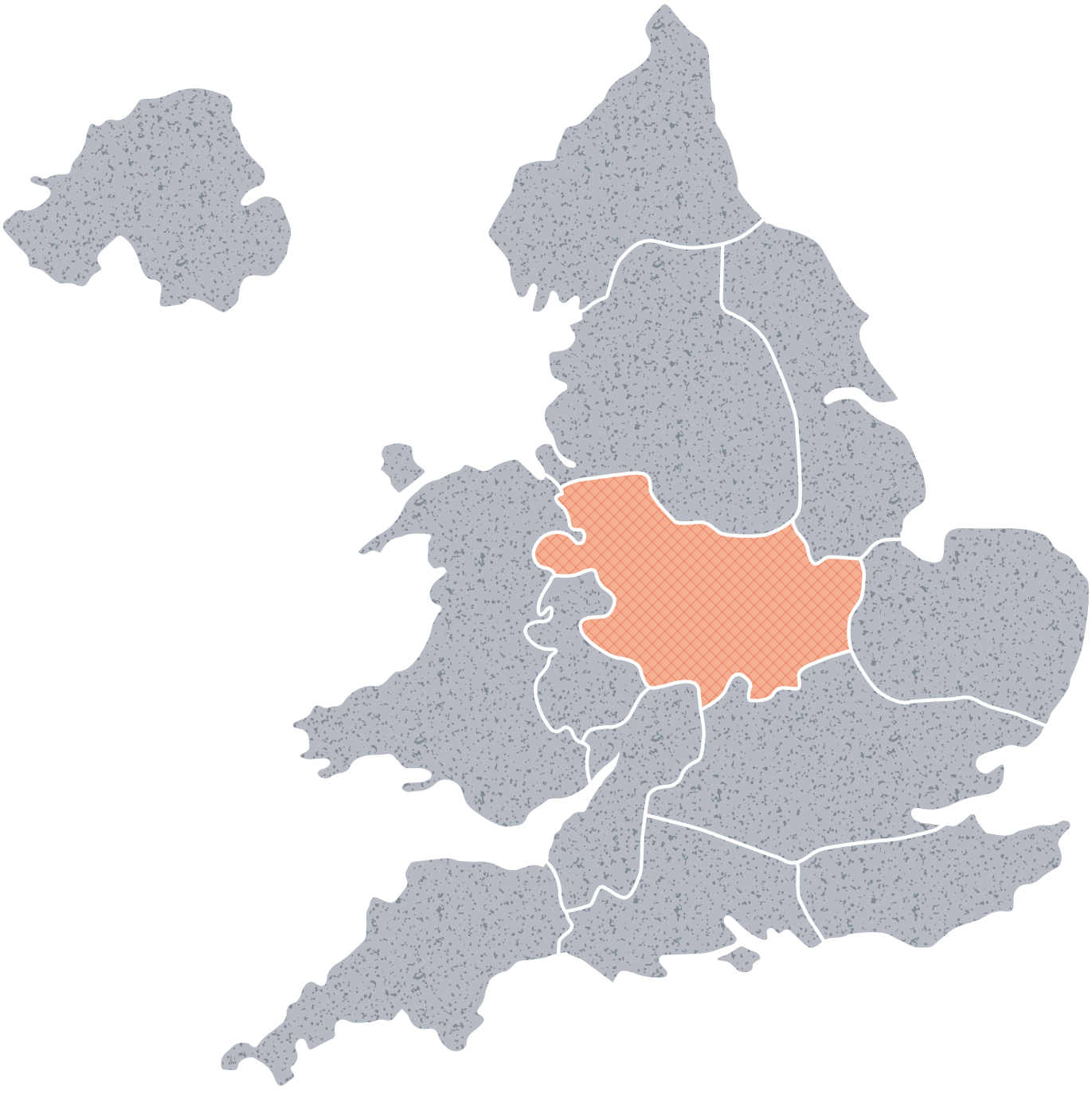
Radioactive Waste Management



Central England

REGIONAL GEOLOGY

Contents

Clicking on words in green, such as sedimentary or lava will take the reader to a brief non-technical explanation of that word in the Glossary section. By clicking on the highlighted word in the Glossary, the reader will be taken back to the page they were on.

Clicking on words in blue, such as Higher Strength Rock or groundwater will take the reader to a brief talking head video or animation providing a non-technical explanation.

For the purposes of this work the BGS only used data which was publicly available at the end of February 2016. The one exception to this was the extent of Oil and Gas Authority licensing which was updated to include data to the end of June 2018.

Introduction

This region covers the English Midlands including Northamptonshire, Leicestershire, Rutland, Warwickshire, Staffordshire and West Midlands and parts of Derbyshire, Nottinghamshire, Worcestershire, Cheshire and Shropshire.

Subregions

To present the conclusions of our work in a concise and accessible way, we have divided the region into 3 subregions (see Figure 1 below). We have selected subregions with broadly similar geological attributes relevant to the safety of a GDF, although there is still considerable variability in each subregion. The boundaries between subregions may locally coincide with the extent of a particular Rock Type of Interest, or may correspond to discrete features such as faults. Although screening has focused on the 200 to 1,000m depth range, which is consistent with the Implementing Geological Disposal White Paper and National Geological Screening Guidance, we recognise that some rock types may be suitable as host rocks where they occur at depths greater than 1,000m.

Central England: summary of the regional geology

What follows is a summary of the geology of the region, emphasising the geological attributes that are relevant to meeting the safety requirements for a GDF. Information about the geology of the region has been summarised by the British Geological Survey (BGS) in a Technical Information Report (TIR) on which this summary is based. This information comes from geological mapping, geophysical surveys and boreholes.

Available information for this region

There are many boreholes extending below 200m in this region, most associated with the coalfields, salt mining and areas of hydrocarbon exploration. Over 150 boreholes extend to depths greater than 1,000m. Geophysical investigations include studies of the Earth's gravity and magnetic fields and seismic surveys. Of these, detailed seismic surveys have mainly been undertaken in parts of the region that have been prospected for deep coal or hydrocarbons. There are a number of shallower boreholes that provide information on the groundwater above 200m, but very little information within and deeper than the depth range of interest for a GDF, 200 to 1,000m below NGS datum.

Rock type

In order to describe the rocks present in the region we have divided them into 3 main groups: younger sedimentary rocks, older sedimentary rocks and basement rocks. These are summarised in Figure 2, which has been drawn up to show the oldest and deepest rocks at the bottom of the schematic rock column, with progressively younger rock units towards the top. Figure 3 is a geological map of the region showing where the major rock units occur at the surface. Figures 4 and 5 present schematic vertical cross-sections through the region. Within the 3 groups, individual rock units have been identified as Rock Types of Interest for the development of a GDF; Higher Strength Rock (HSR), Lower Strength Sedimentary Rock (LSSR) and Evaporite. Figures 6a to 6d show where in the region there are likely to be Rock Types of Interest for the development of a GDF within the depth range of interest.

Younger sedimentary rocks

The youngest rocks present within the depth range of interest are Lower Jurassic sedimentary rocks of the Lias Group (approx. 200 million years old), which occur in the easternmost part of the region and also in a small area around Prees in Shropshire.
The Lias Group overlies a sequence of Triassic and Permian rocks (approx. 200 to 300 million years old) which are widespread across the region. The thicknesses of the Permian and Triassic rocks vary considerably because faults were active when they were being deposited and gave rise to several distinct sedimentary basins. We refer to the Jurassic, Triassic and Permian rocks as the younger sedimentary rocks. This rock sequence is largely made up of sandstones and mudstones with minor limestones and associated evaporite sequences, including bodies of gypsum and anhydrite as well as rock salt (halite). There are several units in the younger sedimentary rock sequence that contain thick mudstones and are likely to behave as LSSR. The rock salt layers also have potential to act as Evaporite host rocks.

Older sedimentary rocks

In the central part of the region, Carboniferous sedimentary rocks (deposited approx. 300 to 360 million years ago) occur in distinct fault-bounded basins. The most widespread rocks in the depth range of interest for screening are the Warwickshire Group and the Pennine Coal Measures Group, both containing a variable mix of sandstones, siltstones and mudstones with coals, but older Carboniferous rocks including Millstone Grit and Carboniferous Limestone Supergroup are also present in the range of interest for screening. In the south-westernmost part of the region, Carboniferous rocks are underlain by sandstones, siltstones and mudstones of the Devonian Upper and Lower Old Red Sandstone Groups (approx. 360 to 420 million years old). We refer to the Carboniferous and Devonian rocks of the region as the older sedimentary rocks which act as a cover to older basement rocks. At the time they were deposited there was intermittent volcanic activity in Central England and examples of igneous rocks are locally associated with these sedimentary rocks.

Basement rocks

Across much of the region, the basement rocks, which underlie the Devonian and younger rocks within the depth range of interest, are sedimentary rocks of Silurian, Ordovician or Cambrian age (approx. 420 to 540 million years old). In some parts of the region it is likely that these have been sufficiently deeply buried and folded to metamorphose the mudstones to become slaty or schist-like. In the eastern part of the region, some of the basement is made up of older igneous and metamorphic rocks (approx. 540 to 630 million years old) including the Charnian rocks, exposed at the surface in Leicestershire. The basement rocks locally contain granitic intrusions of uncertain age. Information on the distribution of different types of basement rock beneath the Devonian and younger rocks is based on geophysical studies and limited sampling from boreholes. Some of the basement rocks have potential as HSR host rocks.

Rock structure

The eastern part of the region has basement rocks close to the surface and there are few major faults (Figure 7). The older sedimentary rocks were deposited in fault-controlled basins, and then uplifted at the end of the Carboniferous period resulting in partial or complete erosion of the Carboniferous rocks in some areas. Subsequent Triassic and younger sedimentary rocks progressively infilled this partially eroded Carboniferous landscape (Figures 4 and 5). Considerable differences in the thicknesses of individual sedimentary units were controlled by faults that were active during deposition, particularly within the Triassic sedimentary sequence.

Faults occur on a diverse range of scales, from centimetres to kilometres, and the subsurface is criss-crossed by networks of numerous individual faults. However our work includes only those faults identified by the BGS with throws (vertical offset) of 200m or more. This is because the data available to the BGS are not able to resolve all faults consistently, across all thirteen regions, with throws less than 200m.

Groundwater

There is very little information on groundwater in the depth range of interest for a GDF, 200 to 1,000m below NGS datum, although there is information on groundwater in aquifers above 200m. The region contains several principal aquifers. They include sandstones and limestones from the older and younger sedimentary rock sequences and the Sherwood Sandstone Group, which is widespread across the region. Where it is present at the surface, the Sherwood Sandstone Group yields good quality water to at least 200m depth. However, water quality commonly deteriorates with increasing depth and where the aquifer is overlain by low permeability mudstones of the Mercia Mudstone Group, inhibiting recharge from rainfall. The distribution of aquifers and the patterns of groundwater flow are strongly influenced by major faults (Figure 7) over much of the region. Groundwater contained in these aquifers is likely to be separated from groundwater at greater depth by low permeability LSSR layers such as the Mercia Mudstone Group even where these layers are not thick enough to host a GDF.

In some other regions, the Carboniferous Limestone aquifer occurs at shallow depths and is a principal aquifer. In this region it is only present below 400m and samples collected from boreholes have shown that the water is saline and therefore not potable. Groundwater from depths greater than 400m is unlikely to be suitable as drinking water anywhere in the UK[1]. There is little evidence for groundwater flow from depth over most of the region except from Droitwich Spa where 45°C brines are present at a depth of 61m.

[1] Water Framework Directive UK TAG. Defining and reporting on groundwater bodies, 2012.

Resources

The region has been of historical importance for its mineral resources, especially coal. The locations of coal mines and Coal Authority Licence Areas are shown in Figure 8a, and locations of hydrocarbon fields and areas covered by Petroleum Exploration and Development Licences[2] in Figure 8b. Areas of historic metal ore mining shallower than 100m are also shown in Figure 8c.

Although coal is not mined today, deep coal remains beneath much of the central and north-western parts of the region. The North Staffordshire, South Staffordshire and Warwickshire Coalfields were the major ones in the region although it also includes the southernmost part of the Nottinghamshire Coalfield. There are several small oil and gas fields in the region.

Rock salt has been mined or extracted as brines from the north-western part of the region for many years, and cavities in salt are also now of interest for gas storage (Figure 8c). There has been a long history of salt production from the south of the region around Droitwich Spa.

The areas where concentrations of deep exploration boreholes would need to be considered in the siting of a GDF are shown in Figure 9.

[2] This also includes other licences awarded by the Oil and Gas Authority to allow companies to explore for hydrocarbons.

Natural processes

The UK has low levels of earthquake activity and correspondingly low seismic hazard. Earthquakes are seldom large enough to be felt and the ground surface is not known to have been broken by active faults. Only 3 earthquakes with a magnitude of 4.0Mw or greater have been recorded in the past 130 years. The largest measured earthquake in the region was the magnitude 5Mw Castle Donington earthquake of 1957, which caused damage to chimneys and roofs in and around Derby, Nottingham and Loughborough.

Whilst the design of a GDF will need to consider the potential impact of future earthquakes, there is no evidence that future seismicity anywhere in the UK would preclude its development.

The region was affected by glaciation during Pleistocene times, with the last major UK glaciation around 12,000 years ago, known as the Devensian, leading to the north-western part of the region being covered by ice, with permafrost throughout the region. The earlier, Anglian, ice sheet covered the entire region. The precise siting and design of a GDF would need to consider the potential impacts of glaciation and permafrost during future continental-scale glaciations. These may include increased erosion and changes to groundwater movement.

Further information

Further information about the geology of the region can be found in the BGS Regional Summary, with additional detail in the BGS Regional Guide. This guide also provides details about many of the sources of information underpinning the TIR.

Figure 1 Subregions of the Central England region as defined for the purpose of National Geological Screening.

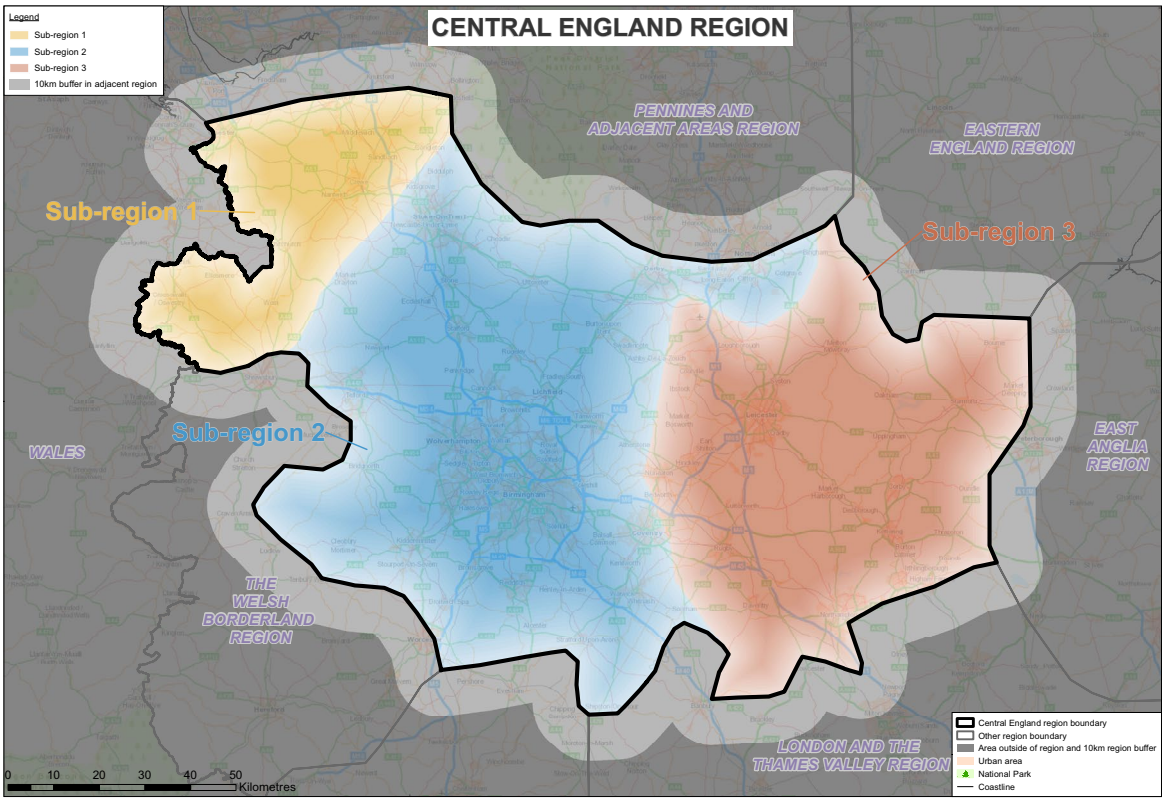
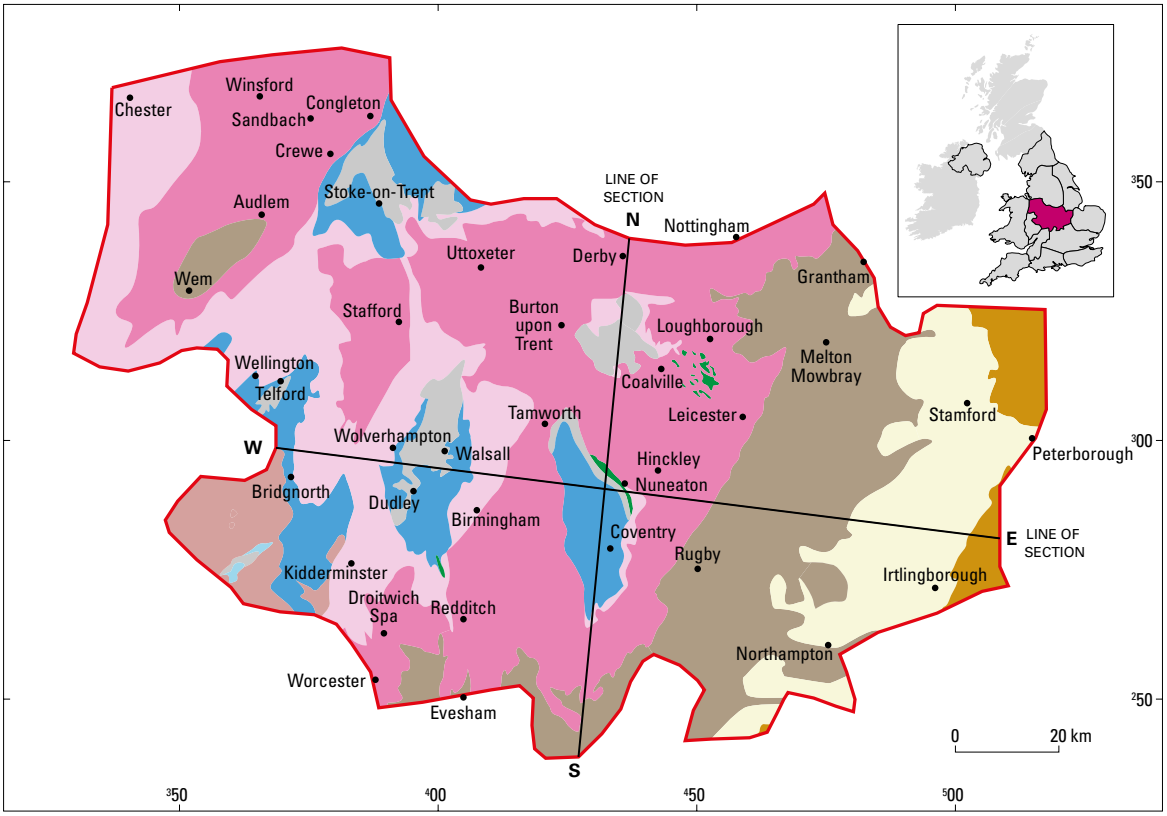


Figure 2 Table illustrating the sequence of the major rock units present in the Central England region and their possible significance for the siting of a GDF.

	Geological Period (age in millions of years)	Geological Unit	Dominant Lithology	Rock types of interest		
				LSSR	HSR	Evaporite
Younger sedimentary rocks	Jurassic (145.0 – 201.3)	Ancholme Group	Not applicable as not within depth range of interest	Not applicable as not within depth range of interest		
		Inferior and Great Oolite Groups	Not applicable as not within depth range of interest	Not applicable as not within depth range of interest		
		Lias Group	mudstone, siltstone, limestone and sandstone	✓		
	Triassic (201.3 – 251.9)	Penarth Group	mudstone and limestone			
		Mercia Mudstone Group	mudstone with local siltstone and evaporite deposits of anhydrite, gypsum and rock salt	✓		✓
		Sherwood Sandstone Group	sandstone, siltstone and mudstone			
	Permian (251.9 – 298.9)	Cumbrian Coast Group (Cheshire Basin) = Zechstein Group (East Midlands)	mudstone, siltstone and sandstone with evaporites including rock salt			
		New Red Sandstone Group (west) = Appleby Group (east)	sandstone and conglomerate			
Older sedimentary and related rocks	Carboniferous (298.9 – 358.9)	Warwickshire Group	siltstone and sandstone	✓		
		Pennine Coal Measures Group	sandstones, siltstones, mudstones and coal			
		Millstone Grit and Craven Group	sandstones, limestones and mudstones			
		Carboniferous Limestone Supergroup	limestones with interbedded mudstones			
		volcanic rocks	lavas and tuffs		✓	
	Devonian (358.9 – 419.2)	Undifferentiated	mudstone, siltstone and sandstone			
Basement rocks	Silurian (419.2 – 443.8)	Pridoli and Ludlow Groups	mudstone, siltstone and sandstone			
		Wenlock, Llandovery and Caradoc Groups	mudstone, siltstone and sandstone		✓	
		Llanvirn and Arenig Groups, volcanic rocks and sills	mudstone, siltstone, sandstone and tuffs			
	Ordovician to Cambrian (443.8 – 541.0)	Melton Mowbray Granodiorite and other igneous rocks	granite and related rocks		✓	
	Cambrian (485.4 – 541.0)	Cambrian to Tremadoc Group rocks, not differentiated	mudstone, siltstone and sandstone			
	Precambrian (older than 541.0)	Avalonian basement (west), Charnian Supergroup (east)	volcanic rocks (lavas, tuffs and other volcanic sediments) and associated intrusions		✓	

Figure 3 Generalised geological map showing the distribution of rock units in the Central England region. The inset shows the extent of the region in the UK. The bold black lines give the locations of the cross-sections shown in Figures 4 and 5. See Figure 2 for the key to the rock types shown.



It should be noted that the area covered by this map is slightly different to the area considered in this document. This is because, unlike the region considered in this study, it refers to the BGS Regional Guide area which does not strictly follow the national boundary of Wales.

Figure 4 Schematic east to west cross-section through the Central England region. Line of section is shown in Figure 3. Note that the vertical scale is greatly exaggerated and actual dips of rock layers are much gentler than they appear here. See Figure 2 for the key to the rock types shown.

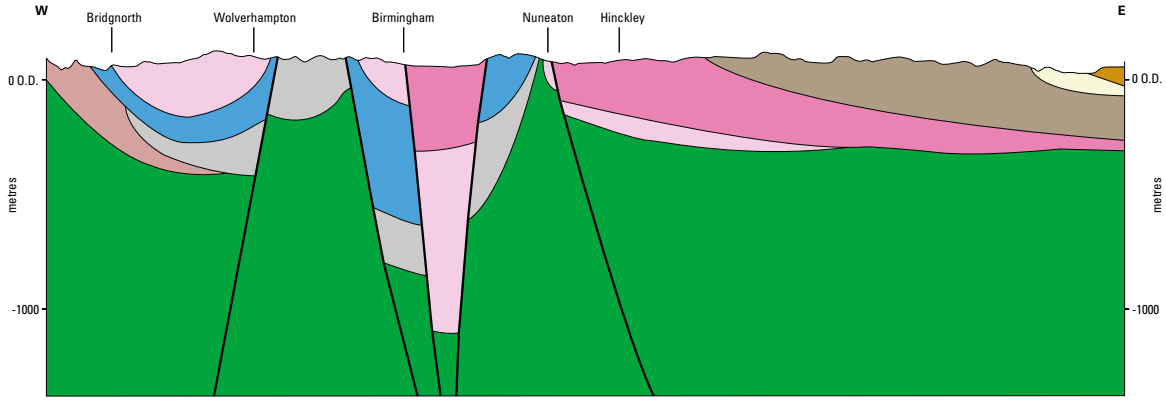


Figure 5 Schematic north to south cross-section through the Central England region. Line of section is shown in Figure 3. Note that the vertical scale is greatly exaggerated and actual dips of rock layers are much gentler than they appear here. See Figure 2 for the key to the rock types shown.

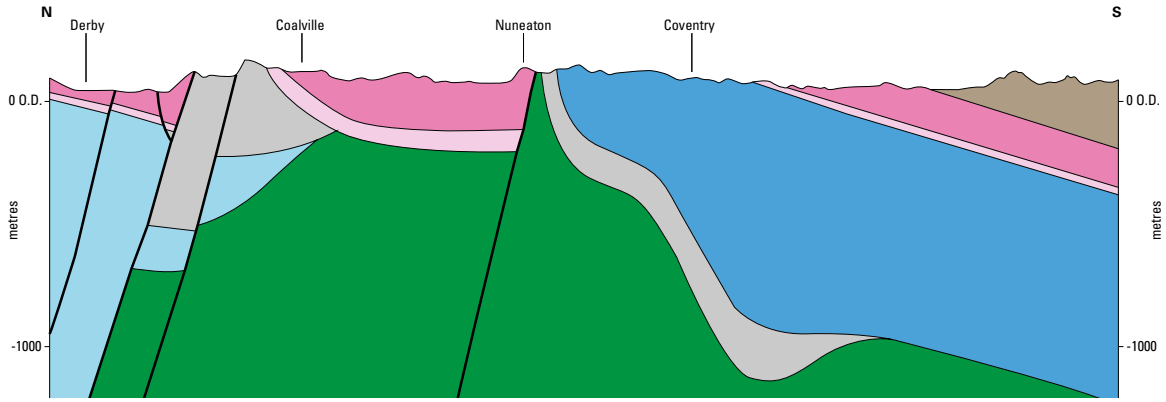


Figure 6a The areas of the Central England region where any of the 3 Rock Types of Interest are present between 200 and 1,000 m below NGS datum.

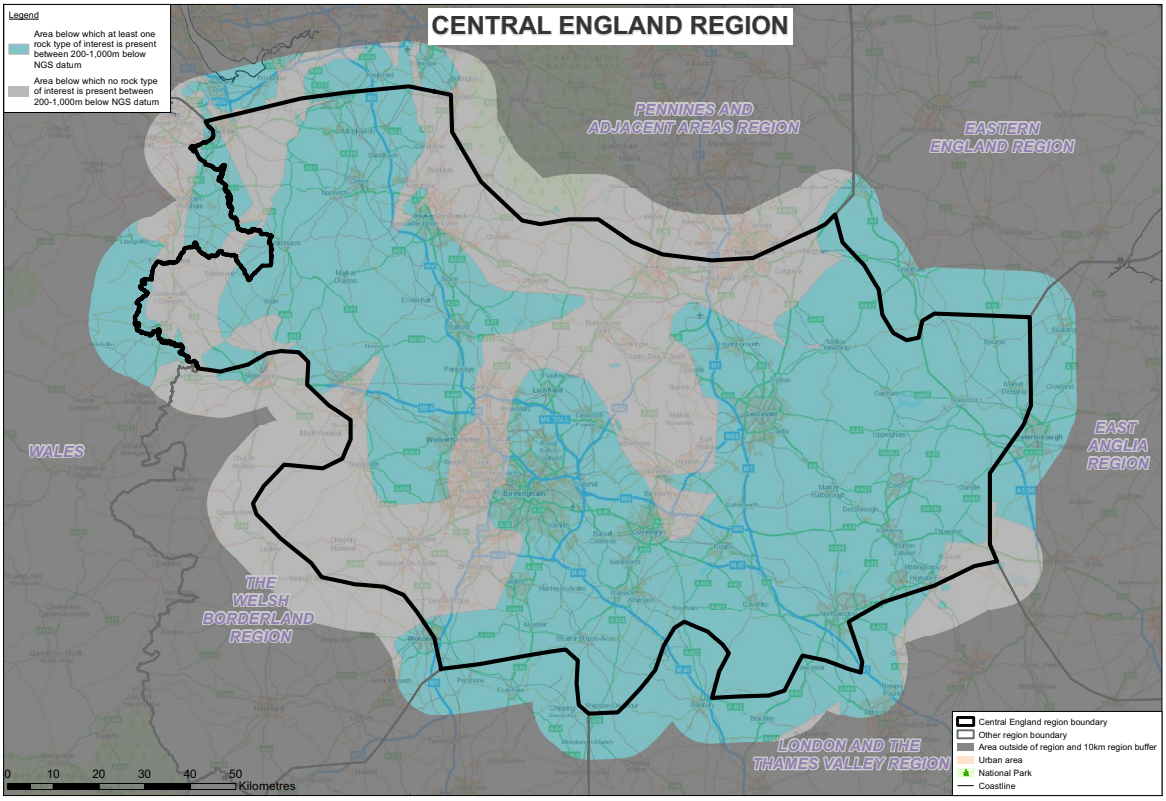


Figure 6b The areas of the Central England region where Lower Strength Sedimentary Rock Types of Interest are present between 200 and 1,000 m below NGS datum.

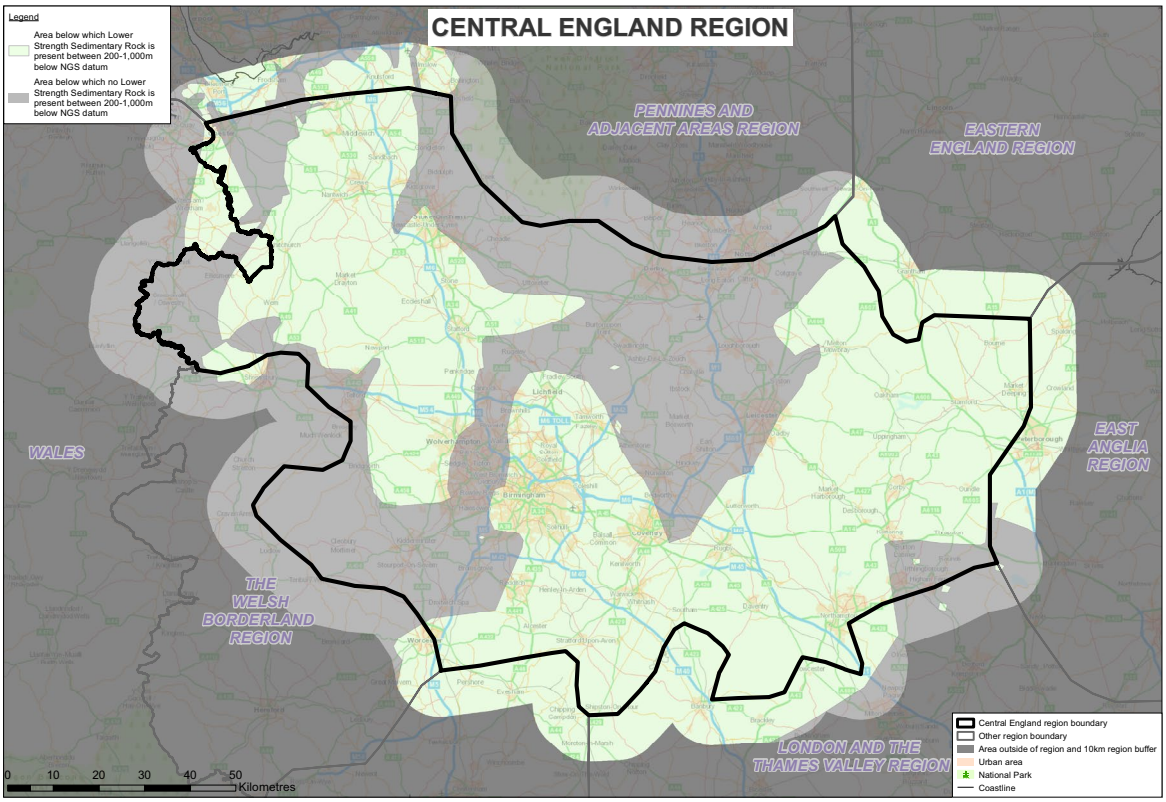


Figure 6c The areas of the Central England region where Higher Strength Rock Types of Interest are present between 200 and 1,000 m below NGS datum.

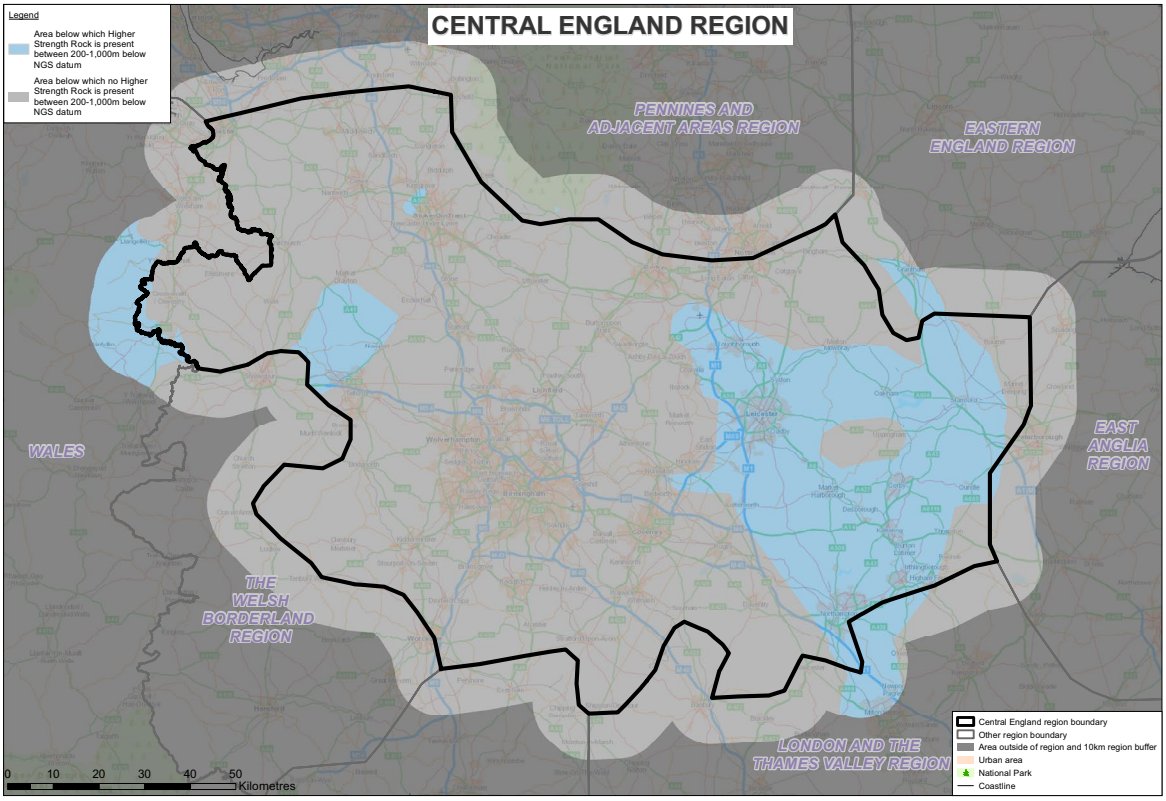


Figure 6d The areas of the Central England region where Evaporite Rock Types of Interest are present between 200 and 1,000 m below NGS datum.

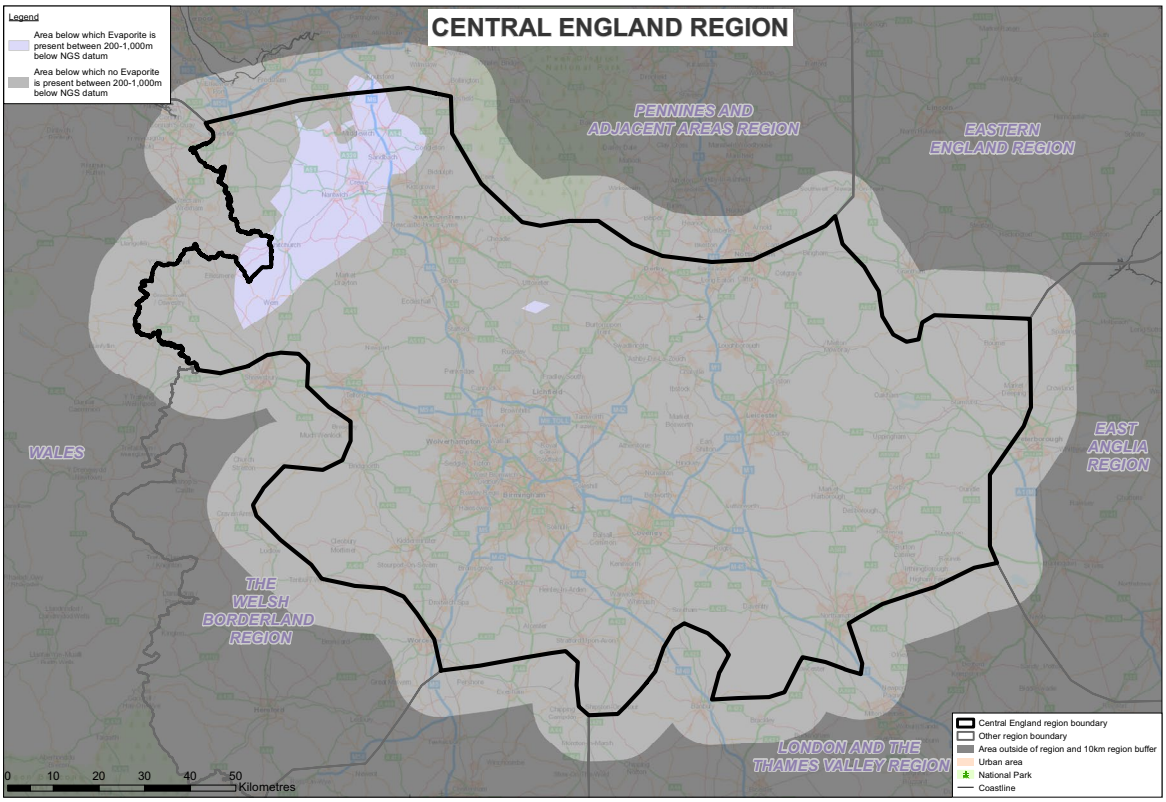


Figure 7 Location of major faults in the Central England region.

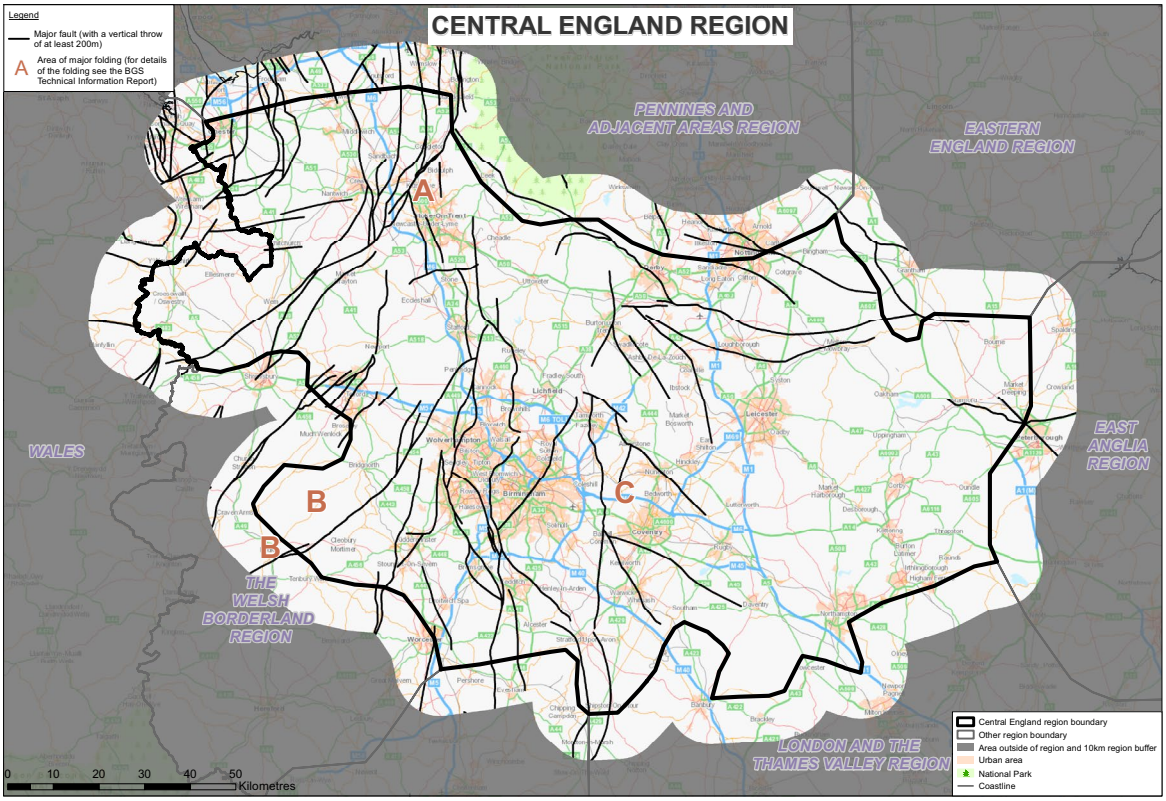


Figure 8a Areas of the Central England with coal mines more than 100m deep and Coal Authority Licence Areas.

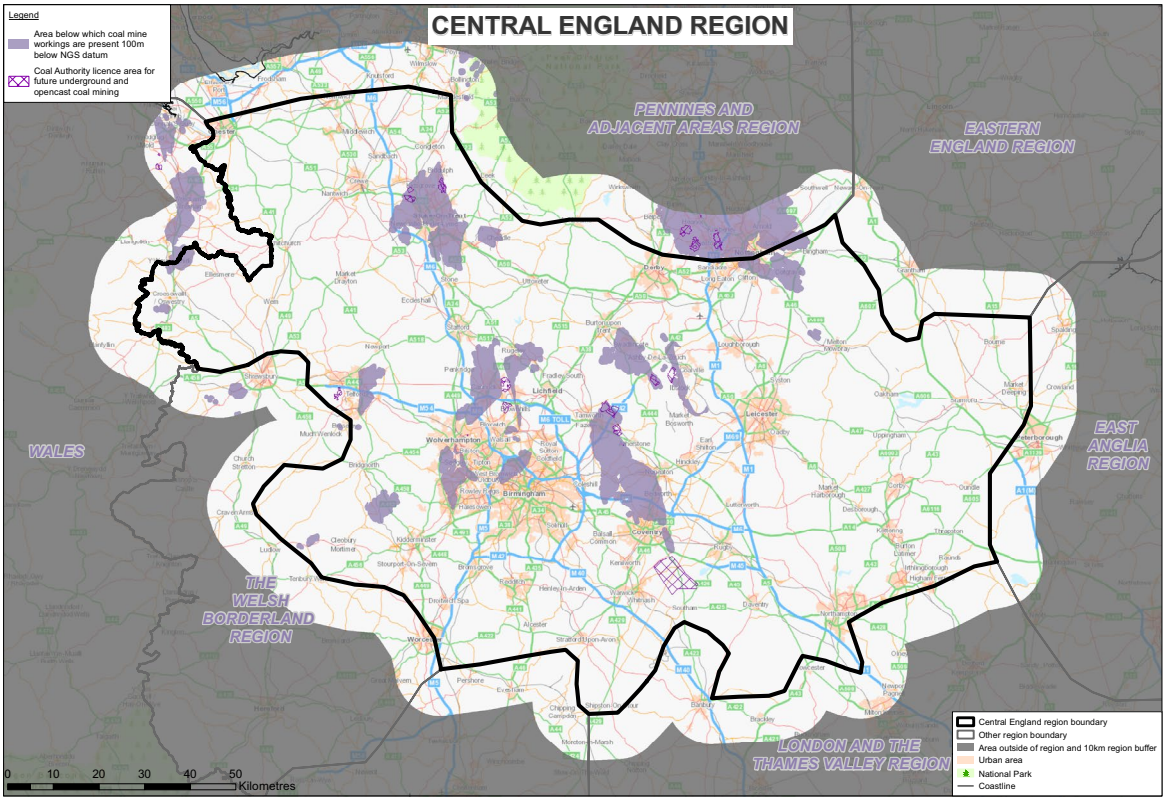


Figure 8b Areas of the Central England region with oil and gas fields and Petroleum Exploration and Development Licences.

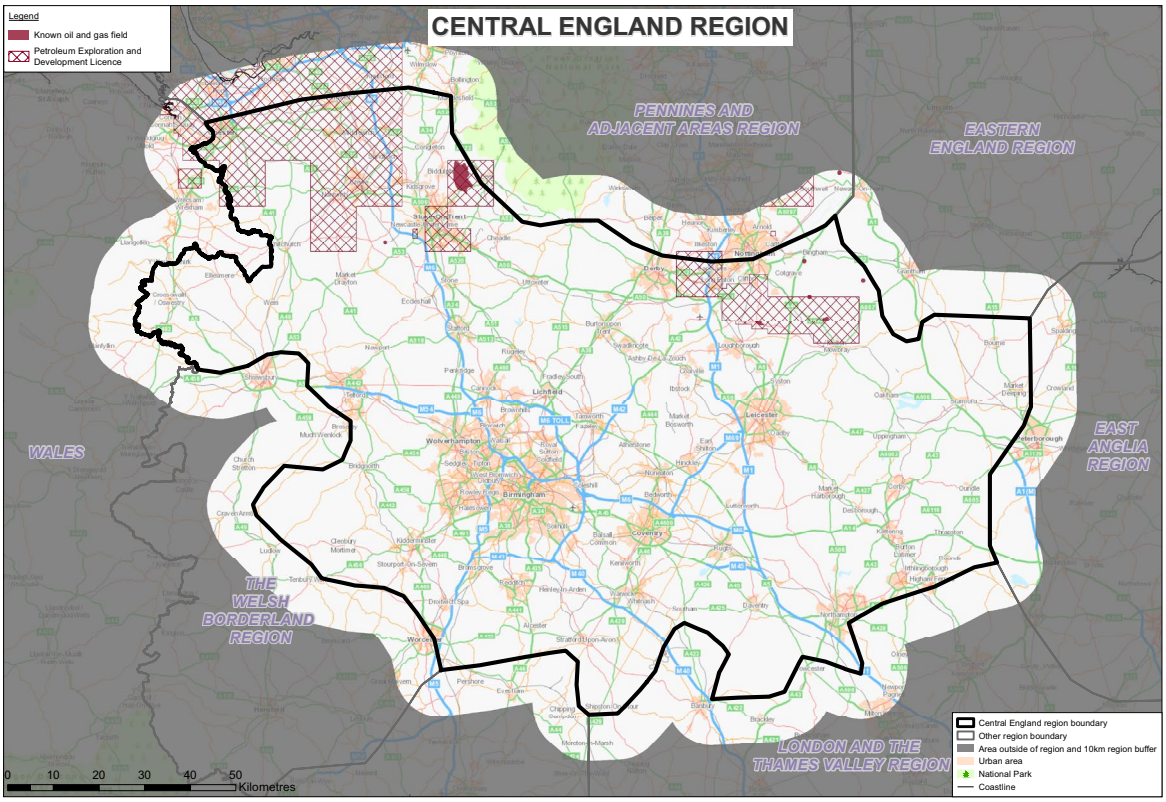


Figure 8c Areas of the Central England region with evaporite mines and historical iron ore mines less than 100m deep.

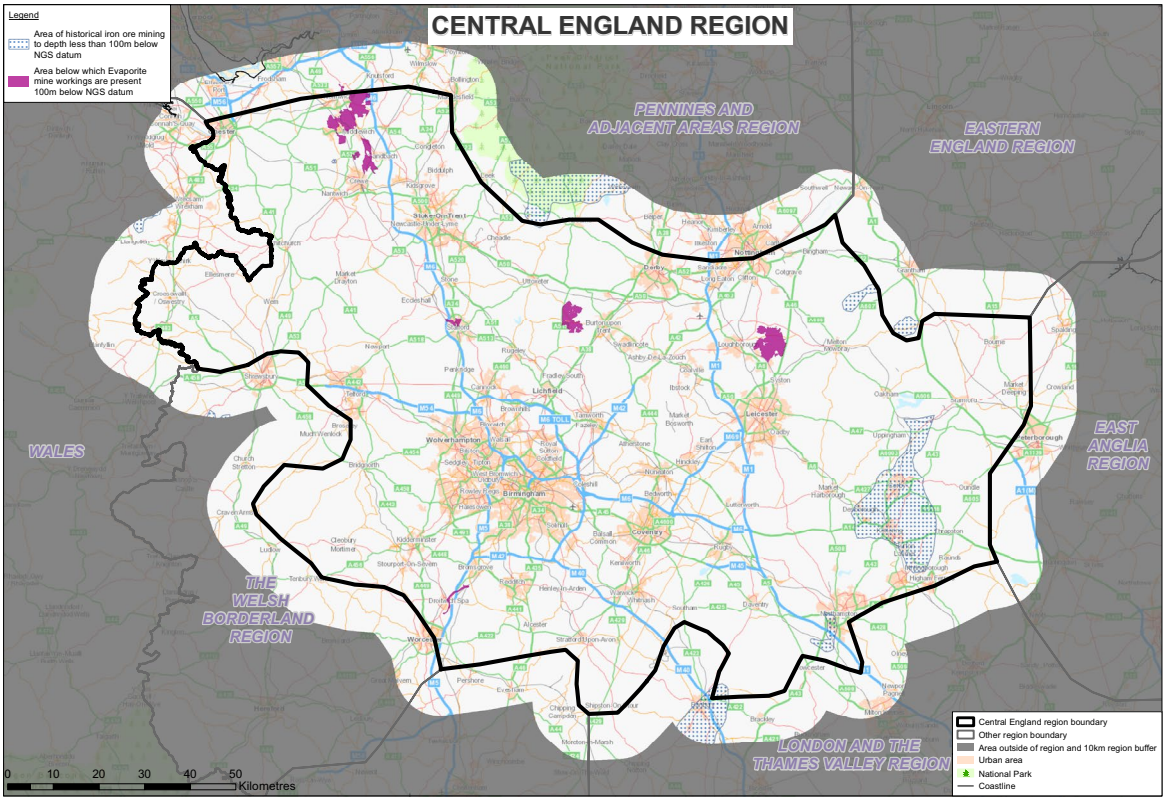
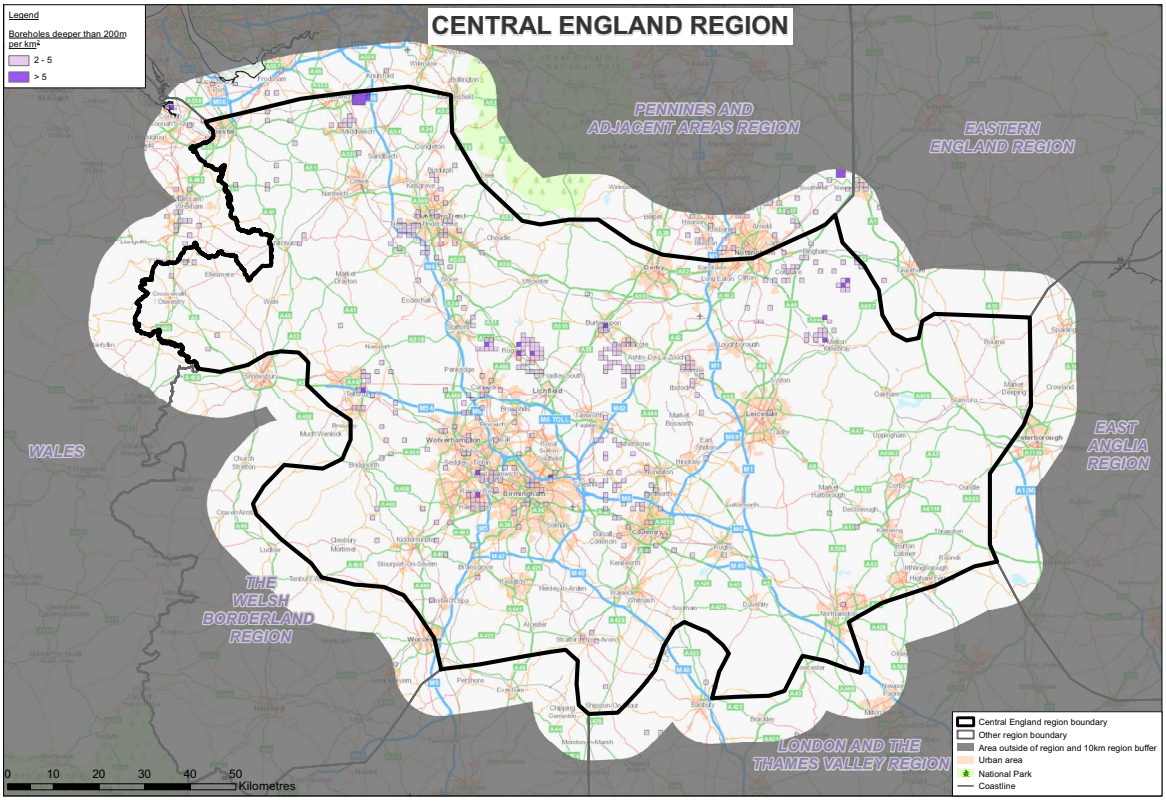


Figure 9 Areas in the Central England region with concentrations of deep exploration boreholes.



Glossary

Active faults
A fault that has moved once or more in the last 10,000 years and is likely to become the source of an earthquake at some time in the future.

Anglian
A glaciation event during the last ice age about 450,000 years ago, where ice sheets extended as far south as the Severn and Thames Estuaries.

Anhydrite
A calcium sulphate mineral that forms from the evaporation of salty seas. It contains no water and occurs at greater depths and higher temperatures than gypsum.

Aquifers
Aquifers are rocks that contain freshwater in pores and/or fractures and whose porosity and permeability are sufficiently high to make the extraction of groundwater possible.

Brines
Water that is either saturated with dissolved salts, or contains a large amount of dissolved salt. An example of a brine is seawater.

Devensian
The most recent glacial period, popularly known as the last Ice Age, which occurred from c.110,000 to 12,000 years ago.

Dip
The angle, or slope of a plane, such as sedimentary layering, measured relative to the horizontal.

Erosion
The process by which the land surface is worn down, mainly by the action of rain, rivers, ice and wind leading to removal of huge volumes of soil and rock particles.

Evaporite sequences
A layering of different types evaporite minerals that forms due to the differing composition of the water that is evaporating to form them.

Fault
A fracture in the earth’s crust across which the rock layers each side of it have been offset relative to one another.

Fault-bounded basins
A depression formed at the surface of the earth's crust which is located on the downthrown side of a fault. These depressions provide space for sequences of sedimentary rocks to accumulate.

Granitic
Pale-coloured, coarse crystalline igneous rock rich in silica, sodium, calcium and potassium.

Gypsum
A calcium sulphate mineral that forms from the evaporation of salty seas. It contains water and occurs at shallower depths and lower temperatures than anhydrite.

Halite
A sodium chloride evaporite mineral that forms when salty water dissolves. Also known as rock salt, or just 'salt'.

Hydrocarbon
A compound of hydrogen and carbon. Hydrocarbons are the chief components of oil and natural gas.

Igneous
One of three main rock types (the others being sedimentary and metamorphic), consisting of hard, dense rocks made up of interlocking crystals. They form due to cooling of magma deep within the crust beneath volcanoes, or as lavas erupted at the surface.

Lithology
The physical properties of rock types.

Pleistocene
The Pleistocene describes the period of geological time between c.2.5 million years ago and 11,700 years ago. It represents the time period spanning the world's most recent period of repeated glaciations. This period is sometimes referred to as "the Ice Age" however, "ice age" can refer to several periods throughout geological history.

Potable
Water that is of drinkable quality.

Principal aquifers
An aquifer classified by the Environment Agency as: "rock or drift deposits that have high intergranular and/or fracture permeability – meaning they usually provide a high level of water storage." They represent the most important aquifers in terms of water supply or base flow.

Saline
Containing salt (e.g. seawater is saline).

Schist
Recrystallized metamorphic rocks with a distinctive texture caused by the parallel alignment of tiny crystals of mica. As a result, schists are characteristically sheet-like, rather like the pages of a telephone directory.

Sedimentary
A type of rock resulting from the consolidation of material that has accumulated in layers to form gravel, sandstone, mudstone and limestone. The layers may be built up by movement from erosion (e.g. by rivers, the sea or wind) or by chemical precipitation. Generally, the material that accumulates has originated from the weathering of other rocks. Sedimentary rocks constitute one of the three main classes of rocks identified by geologists, the others being igneous and metamorphic.

Seismic
Shaking in the earth's crust due to natural earthquakes.

Slaty
Distinctive way in which slate rocks split into very fine sheets.

Radioactive Waste Management

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