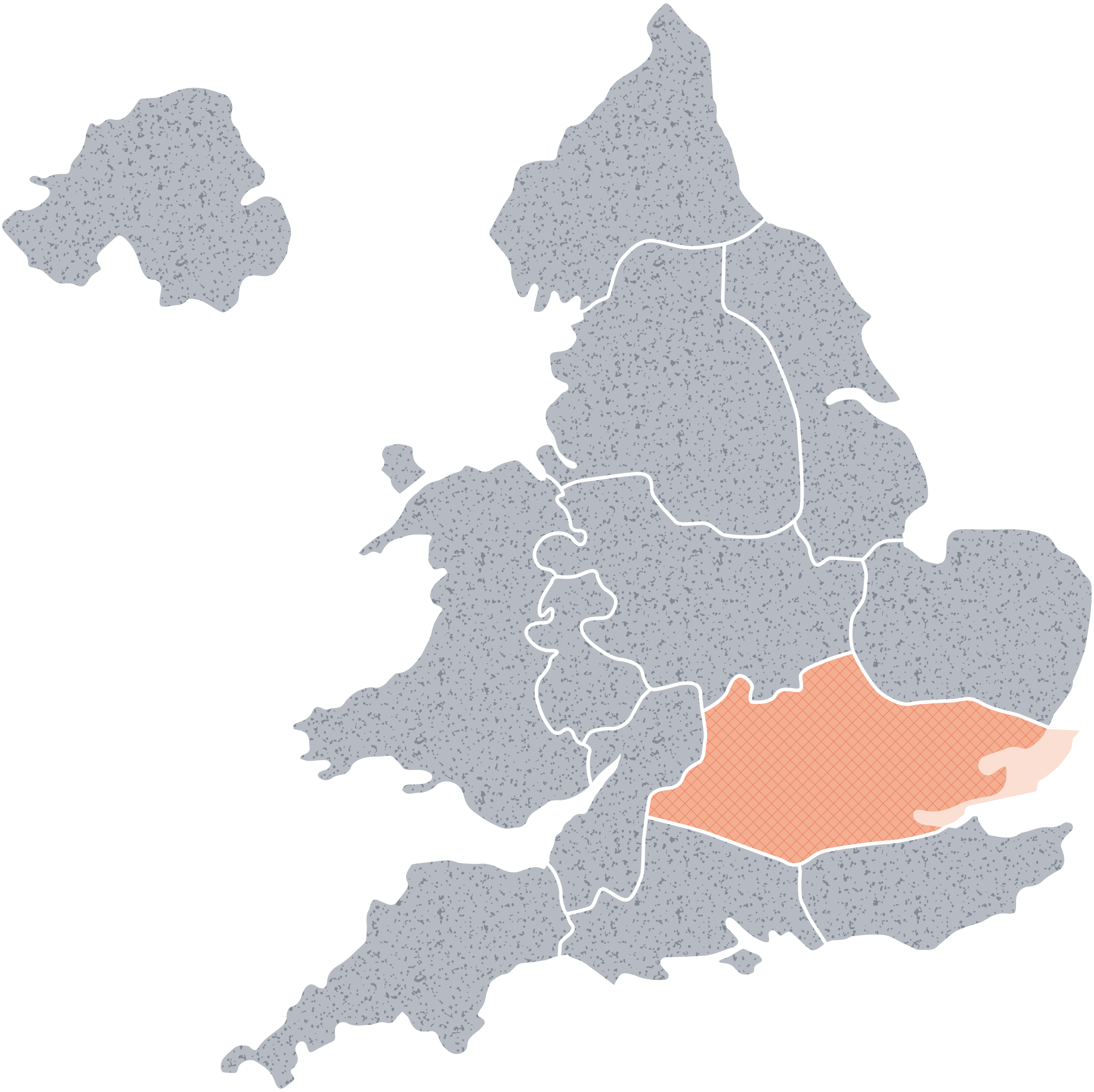
Radioactive Waste Management



London and the Thames Valley

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 extends from Essex and parts of north-west Kent westwards through Greater London, Hertfordshire and Bedfordshire and into Oxfordshire and northern Wiltshire. At its eastern limit the area includes a section of coastline, including the adjacent inshore area which extends to 20km from the coast.

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.

London and the Thames Valley: 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.

The extreme south of the region comprises the North Downs, a major topographical feature composed of Lower Cretaceous rocks.

Available information for this region

There are more than 140 boreholes drilled to more than 200m depth in search for water, coal, oil and gas, in various parts of the region. Some of the deepest boreholes, in the west of the region, reach more than 1km depth. This information is supplemented by geophysical investigations including studies of the Earth's gravity and magnetic fields and seismic surveys. The geology is better understood in parts of the region where boreholes have been drilled or geophysical surveys have been undertaken. 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. They are summarised in Figure 2 which is a simplified rock column showing the oldest and deepest rocks at the bottom, 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 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 6c 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 in the region, such as the London Clay Formation and Crag Sand Group, are well known because they are close to the surface and have been sampled in many boreholes. However, because they do not occur below 200m they are not of relevance to the safety of a GDF and are not therefore discussed here.

Below the London Clay Formation and Crag Sand Group is a sequence of sedimentary rocks that accumulated in the Cretaceous, Jurassic and Triassic periods (approx. 65 to 250 million years ago). They are mainly composed of limestones, sandstones and mudstones and are comparable to rocks of similar age seen along the coasts of Dorset and North Yorkshire. In southern parts of the area, the Cretaceous sequence includes the widespread Chalk Group sediments that underlie the North Downs and form the distinctive white cliffs of Dover and Beachy Head (pale green on Figures 4 and 5). Beneath London, in the central part of the region, Jurassic rocks are absent and the Cretaceous sequence rests directly on pre-Jurassic and older rocks (dark blue green on Figures 4 and 5).

There are several rock units in the younger sedimentary rock sequence which contain thick, extensive mudstone layers and are likely to behave as LSSR. Some of these occur at the surface in the western part of the region and all are well known from drilling across a large part of the region. The Gault, Kimmeridge and Oxford Clay Formations are all in excess of 50m thick over part of the region although they reduce in thickness significantly towards the east.

Older sedimentary rocks

Sedimentary rocks of Carboniferous age (approx. 300 to 360 million years old) are known from boreholes across the region. These are referred to here as older sedimentary rocks and include limestones, sandstones and mudrocks. They have been buried sufficiently deeply such that they are now highly compacted compared to the younger sedimentary rocks above (shown in orange and brown in Figures 4 and 5). These older sedimentary rocks are underlain by crystalline and/or metamorphosed basement rocks.

Basement rocks

The oldest rocks in the region are of Devonian age[1] or older (more than 360 million years old). They form the basement (shown in blue, purple and dark grey on Figures 4 and 5) to the sedimentary rocks that lie above. Some of these basement rocks may have potential as HSR host rocks. They are not exposed at the surface in this region, but many of the same rock units occur at the surface in other regions, such as Central England and the Welsh Borderland. They have also been encountered in deep boreholes across the region although often only the topmost few metres are penetrated. They fall into at least 2 categories, each known from only a small number of widely spaced boreholes:

- Igneous rocks – the result of volcanic activity or formed from the solidification of molten rock below ancient volcanoes; these include Precambrian basaltic andesite lavas encountered in a borehole near Banbury and a granitic intrusion of Ordovician age (approx. 445 to 485 million years ago) encountered in a borehole near Bletchley, to the south of Milton Keynes.
- Rocks of sedimentary origin – a range of mudstones, siltstones, sandstones and limestones were deposited across the region during Silurian to Cambrian times (approx. 420 to 540 million years ago). In some parts of the region, these sedimentary rocks have been folded and metamorphosed so that the mudstones are slaty.

The BGS considers that these igneous rocks are potential HSR host rocks, but that there is insufficient information available at present to know if the basement rocks of sedimentary origin would be suitable to host a GDF.

Rock structure

The younger sedimentary rocks, including most of the potential LSSR host rocks, dip gently and are only rarely cut by major faults (see Figure 7). They were gently folded during the Cenozoic (up to approx. 65 million years ago) to form broad, open dome-shaped folds with widths of the order of tens of kilometres. The older sedimentary rocks are thought to be more deformed though structures within these rocks are generally poorly understood.

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.

[1] The BGS have included all Devonian rocks in this region within the Basement for the purposes of Screening. The reality is that the Lower Old Red Sandstone is deformed, representing final stages of Caledonian mountain building period whereas the Upper Old Red Sandstone lies unconformably on the Lower Old Red Sandstone and represents the basal part of the older sedimentary cover rocks.

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. These include the Chalk Group and several older sandstones and limestones within the younger sedimentary rock sequences. The potential LSSR layers are likely to act as a barrier to vertical movement between aquifers and between deep and shallow groundwater even where they are not thick enough to host a GDF. The Sherwood Sandstone Group and the Carboniferous Limestone aquifer are present within the depth range of interest in this region. In some other regions these rocks occur at shallow depths and are principal aquifers. In this region, the groundwater in these aquifers has not been sampled, however it is likely that it is old saline water rather than potable water as these rocks are not directly connected to the surface and therefore not recharged. Groundwater from depths greater than 400m is unlikely to be suitable as drinking water anywhere in the UK[2].

There are no natural thermal springs in the region to suggest rapid flow of deep groundwater to the surface.

Resources

Despite several centuries of exploitation of shallow resources such as chalk, building stone and sand, there is very little history of, or potential for, resource extraction below 100m in this region. The Oxfordshire and Berkshire Coalfield which lies in the west of the region has been evaluated, but never mined: the coals are thin and of low quality and it is unlikely that exploitation will be considered economic in the future. There are no known hydrocarbon or mineral resources below 100m, although there is an Oil and Gas Authority Licence for a small area at the extreme southern end of this region and a Coal Authority Licence Area in the inshore area off Southend-On-Sea (Figures 8a and 8b).

An area of bedded iron ores which was mined on a modest scale in the 19th century near Banbury is also shown in Figure 8c.

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

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

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. Fewer earthquakes have been recorded over the past few hundred years for the London and the Thames Valley region than in most parts of mainland Britain. There is only one observation of an earthquake with a magnitude of 4.0Mw or greater. This occurred at shallow depth (<5km) near Peldon in Essex, 10km south of Colchester, on 22 April 1884, and caused widespread but generally minor damage to structures.

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

The region has been affected by only one continental-scale glaciation during the last 2.5 million years (the Anglian Glaciation) and it is widely accepted that it is situated beyond the limits of highland- and lowland-scale glaciations. 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.

The coastal area in the east of the region is susceptible to future groundwater changes in response to sea level change. The precise siting and design of a GDF would therefore consider the potential impacts of sea level change.

Further information

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

Figure 1 Subregions of the London and the Thames Valley region as defined for the purpose of National Geological Screening.

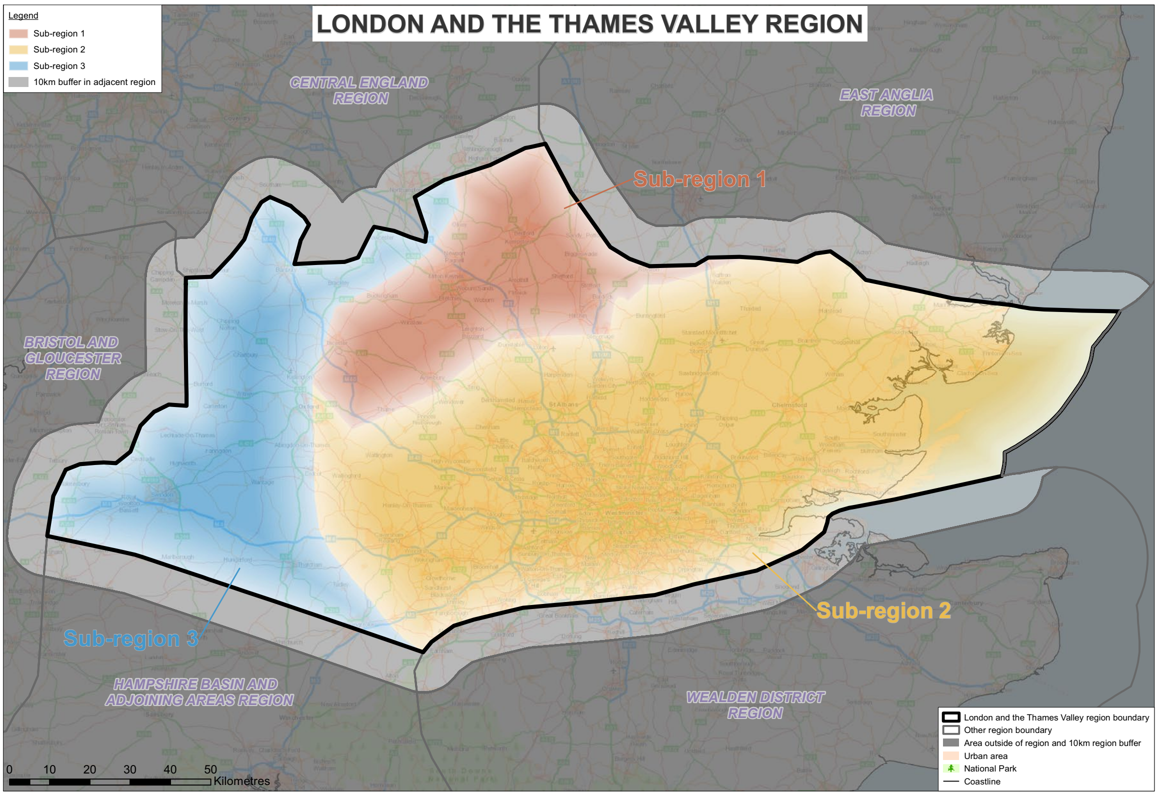


Figure 2 Table illustrating the sequence of the major rock units present in the London and the Thames Valley region and their possible significance for the siting of a GDF[3].

	Geological Period (age in millions of years)	Geological Unit	Dominant Lithology	Rock types of interest		
				LSSR	HSR	Evaporite
Younger Sedimentary Rocks	Palaeogene (23.0 – 66.0)	Barton Group Bracklesham Group Thames Group Lambeth Group	Not applicable as not in depth range of interest	Not applicable as not in depth range of interest		
		Thanet Sand Formation	sand, silt and clay			
	Cretaceous (66.0 – 145.0)	Chalk Group	chalk			
		Upper Greensand Formation	sandstone			
		Gault Formation	mudstone	✓		
		Lower Greensand Group	sandstone and mudstone			
		Wealden Group	siltstone, sandstone, mudstone	✓		
		Purbeck Group	interbedded limestone and mudstone			
	Jurassic (145.0 – 201.3)	Portland Group	limestone and calcareous sandstone			
		Kimmeridge Clay Formation	mudstone	✓		
		Ampthill Clay Formation	mudstone	✓		
		Corallian Group	limestone, sandstone, siltstone and mudstone			
		West Walton Formation	mudstone	✓		
		Oxford Clay/Kellaways Formation	mudstone, siltstone and sandstone	✓		
		Great Oolite Group	sandstone, limestone and mudstones			
		Inferior Oolite Group	limestone, sandstone, siltstone and mudstone			
		Lias Group	mudstone, siltstone, limestone and sandstone	✓		
	Triassic (201.3 – 251.9)	Penarth Group	mudstone, limestone and sandstone			
		Mercia Mudstone Group	mudstone, siltstone and sandstone	✓		
		Sherwood Sandstone Group	sandstone, siltstone and mudstone			

[3] Gaps in time in this column with no rock types shown either represent periods when no rocks were being formed or indicate that the rocks formed during these periods have subsequently been removed by erosion.

Figure 2 Cont'd Table illustrating the sequence of the major rock units present in the London and the Thames Valley region and their possible significance for the siting of a GDF[3].

Older Sedimentary Rocks	Carboniferous (298.9 – 358.9)	Warwickshire Group	mudstone, siltstone, sandstone, coal, ironstone and ferricrete	✓		
		South Wales Coal Measures Group	mudstone, siltstone, sandstone, coal, with volcanic and intrusive igneous rocks locally			
		Carboniferous Limestone Supergroup	limestone with mudstone and siltstone			
	Devonian (358.9 – 419.2)	Old Red Sandstone	mudstone, siltstone and sandstone			
Basement Rocks	Silurian, Ordovician and Cambrian (419.2 – 541.0)	Undifferentiated	mudstone, siltstone, sandstone and limestone (may be metamorphosed in part)			
	Neoproterozoic (Pre-Cambrian) (older than 541.0)	Undifferentiated	basaltic lavas and granitic intrusions		✓	

[3] Gaps in time in this column with no rock types shown either represent periods when no rocks were being formed or indicate that the rocks formed during these periods have subsequently been removed by erosion.

Figure 3 Generalised geological map showing the distribution of rock units in the London and the Thames Valley 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.

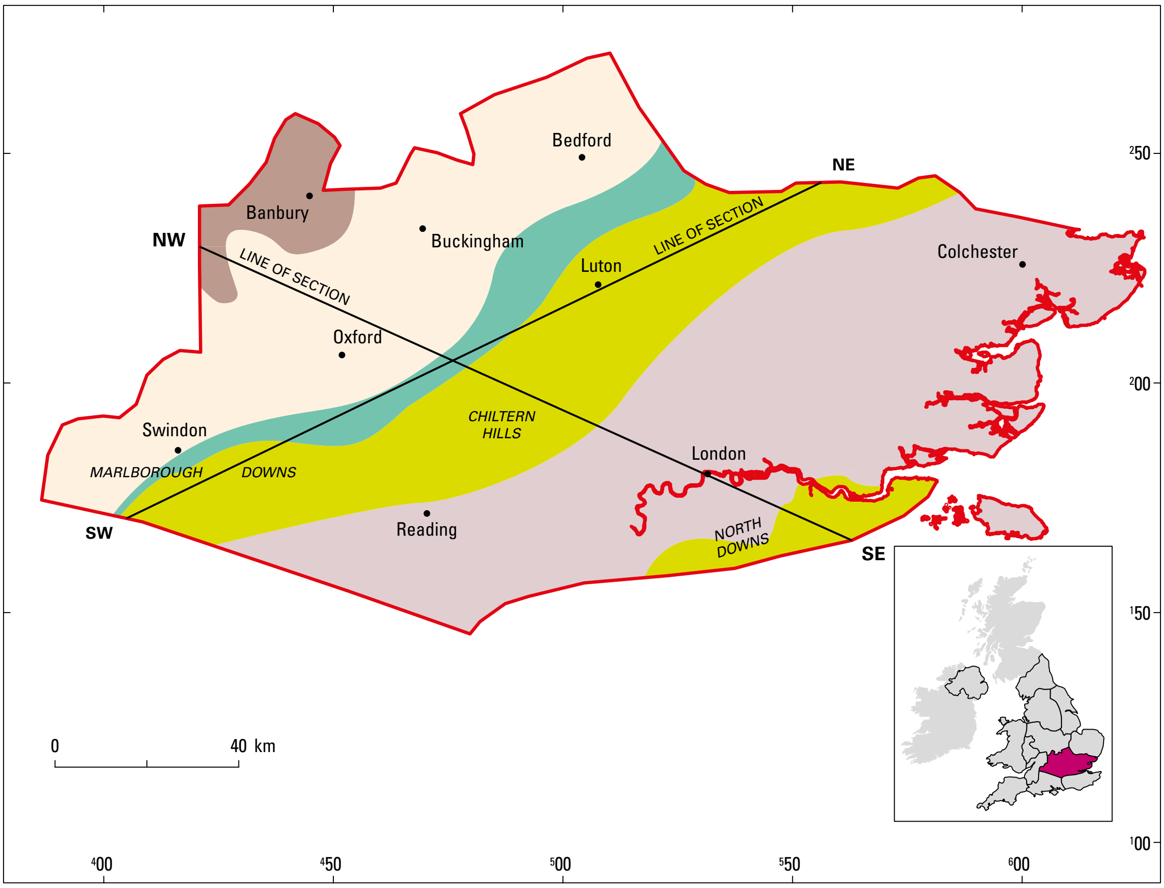


Figure 4 Schematic south-west to north-east cross-section through the Thames Valley from the Marlborough Downs to the Chiltern Hills. Line of section is shown in Figure 3. Note that the vertical scale is greatly exaggerated and actual dips of rock layers are much gentler than they appear here. See Figure 2 for the key to the rock types shown.

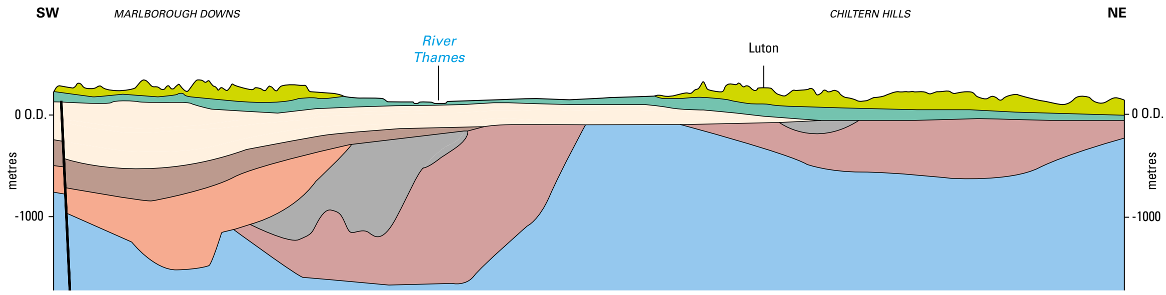


Figure 5 Schematic north-west to south-east cross-section through the Thames Valley, passing through London. Line of section is shown in Figure 3. Note that the vertical scale is greatly exaggerated and actual dips of rock layers are much gentler than they appear here. See Figure 2 for the key to the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

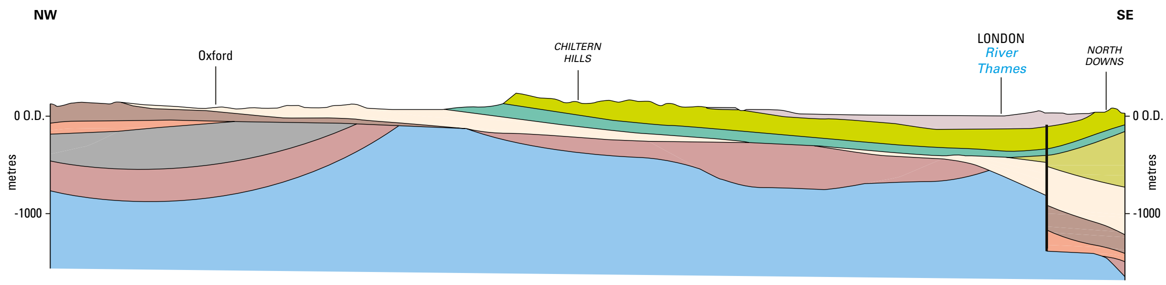


Figure 6a The areas of the London and the Thames Valley region where any of the 3 Rock Types of Interest are present between 200 and 1,000m below NGS datum.

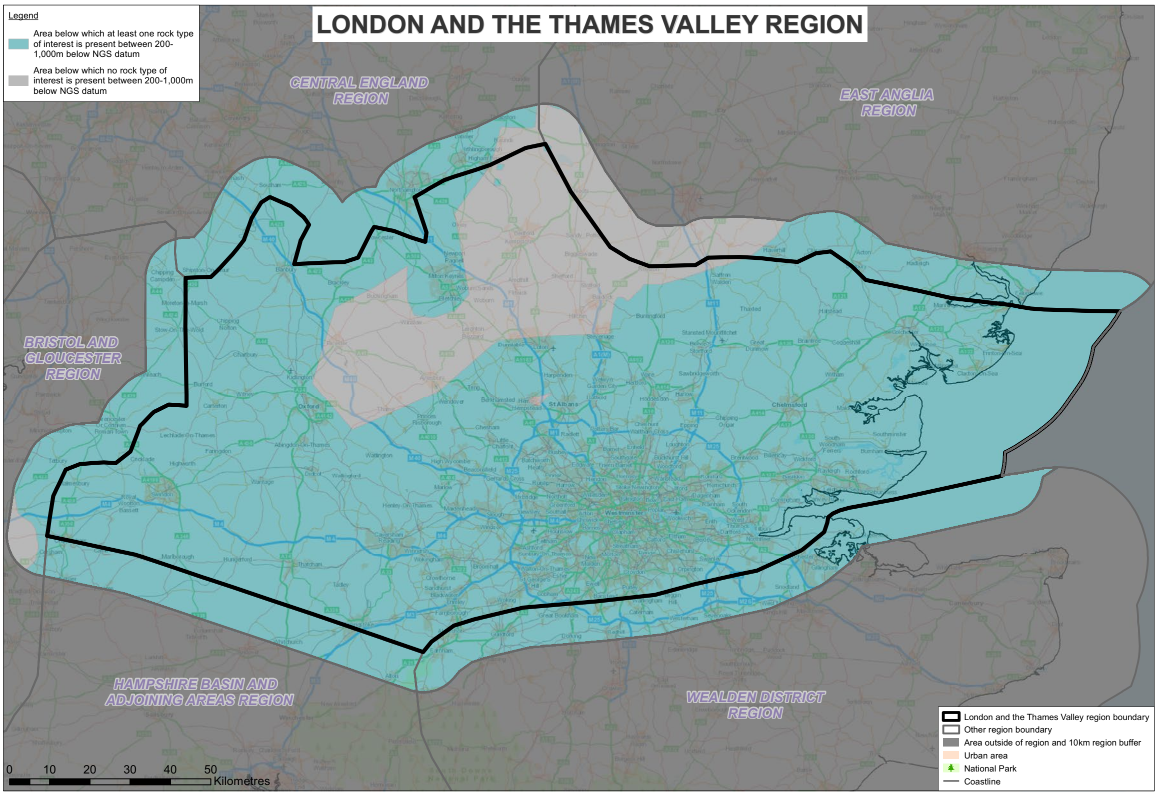


Figure 6b The areas of the London and the Thames Valley region where Lower Strength Sedimentary Rock Types of Interest are present between 200 and 1,000 m below NGS datum.

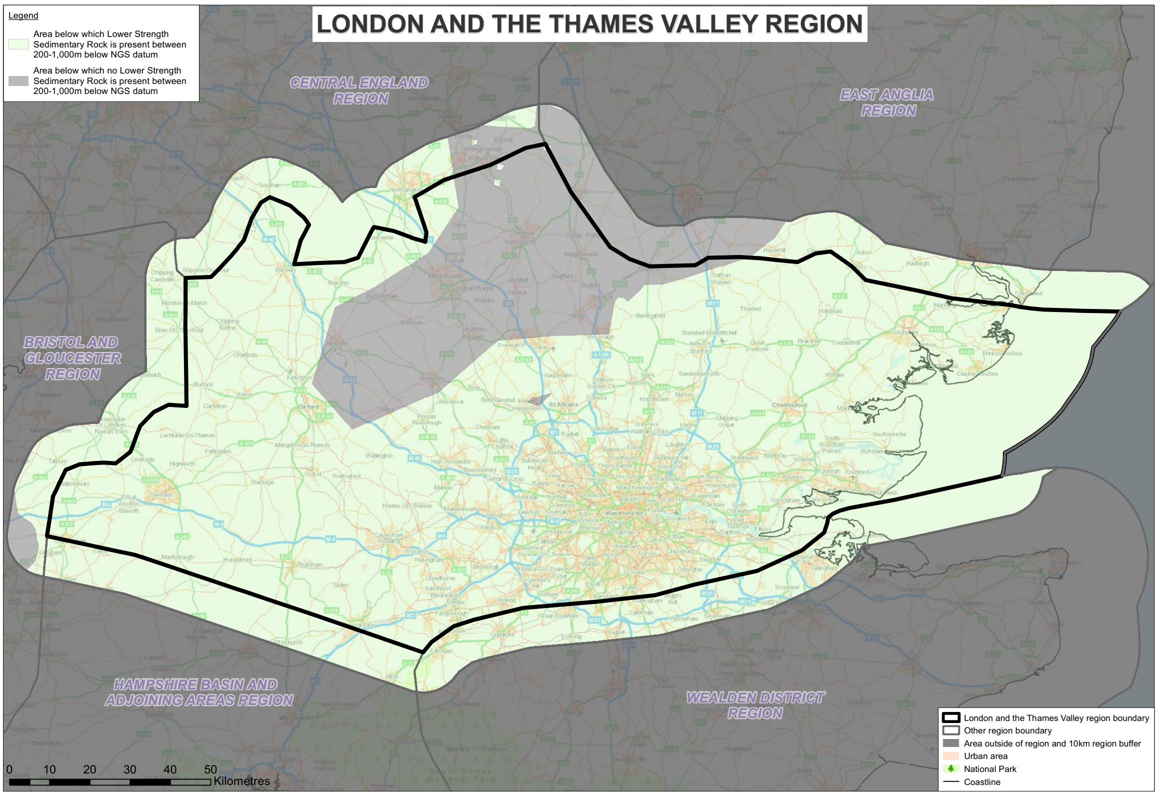


Figure 6c The areas of the London and the Thames Valley region where Higher Strength Rock Types of Interest are present between 200 and 1,000 m below NGS datum.

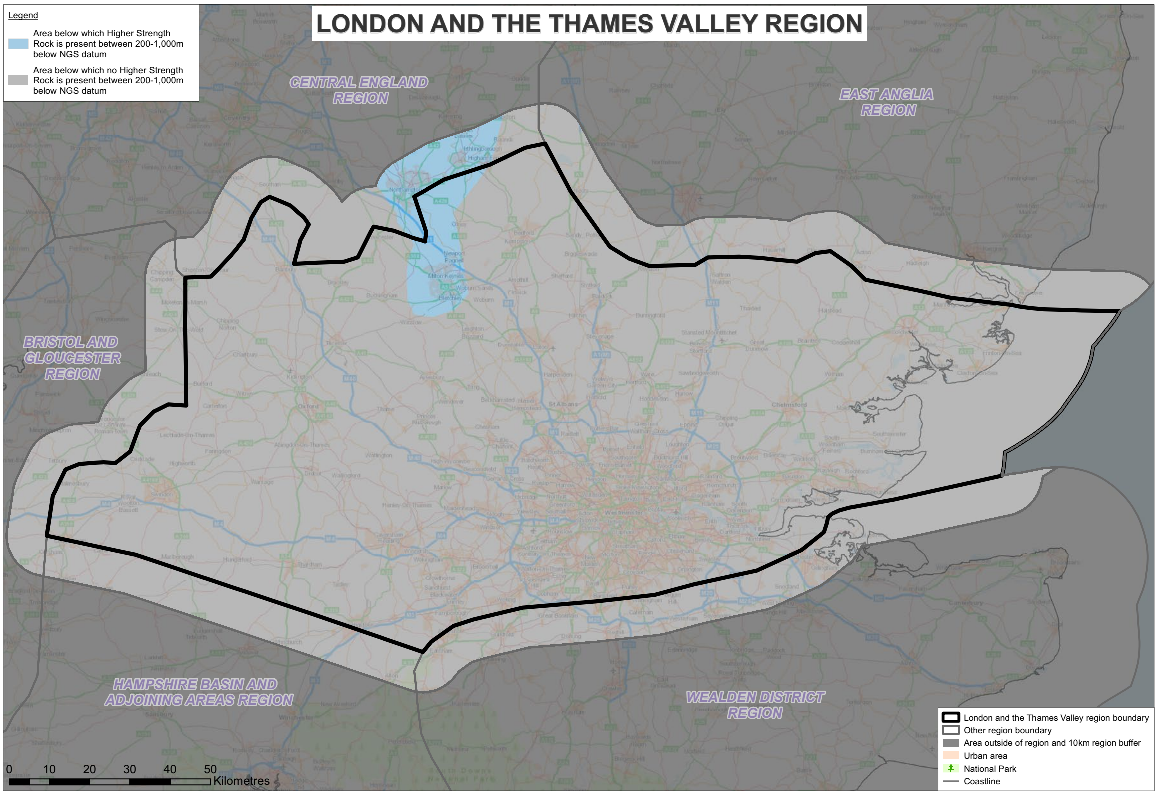


Figure 7 Location of major faults in the London and the Thames Valley region.

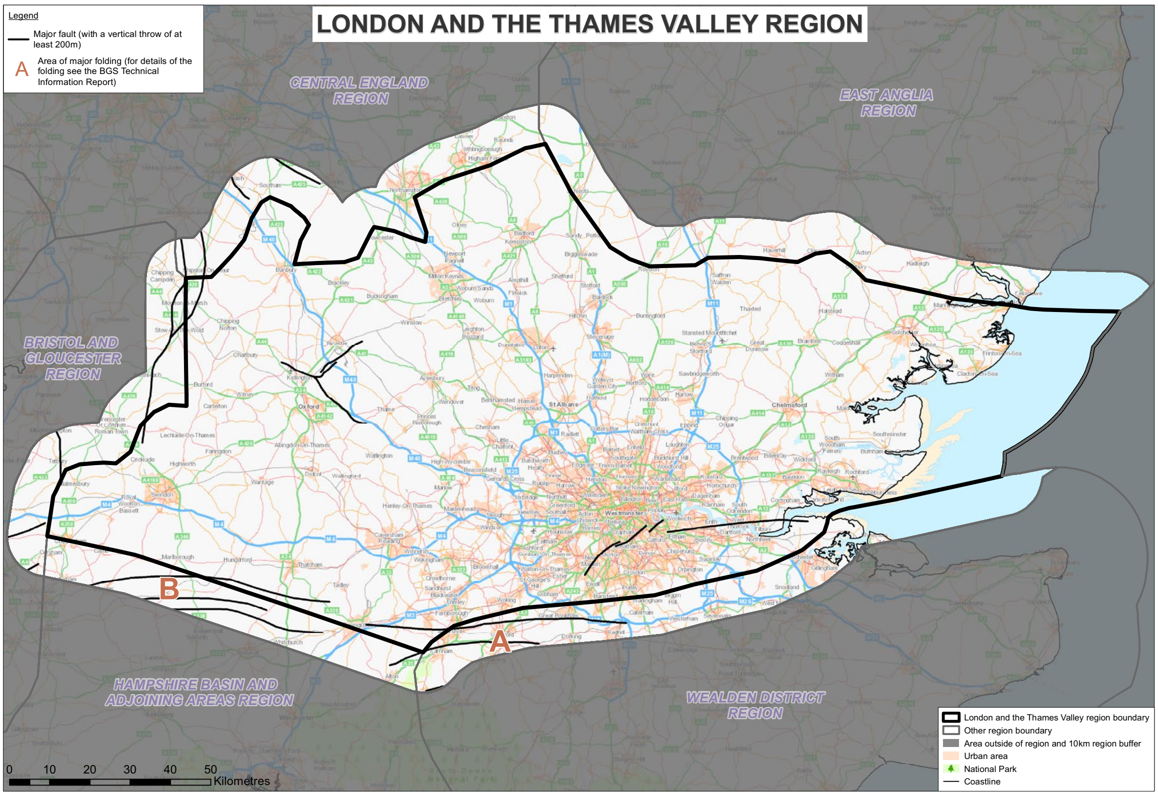


Figure 8a Areas of the London and the Thames Valley region with Petroleum Exploration and Development Licences.

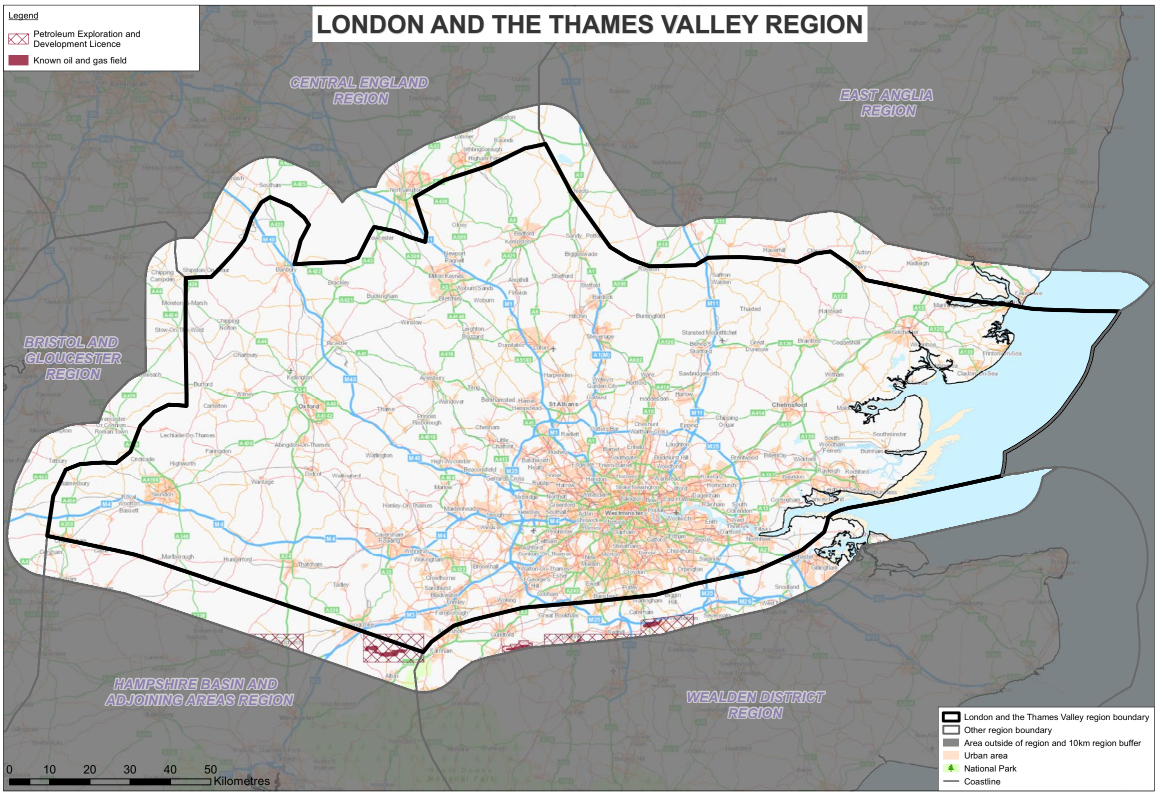


Figure 8b Areas of the London and the Thames Valley region with Coal Authority Licence Areas

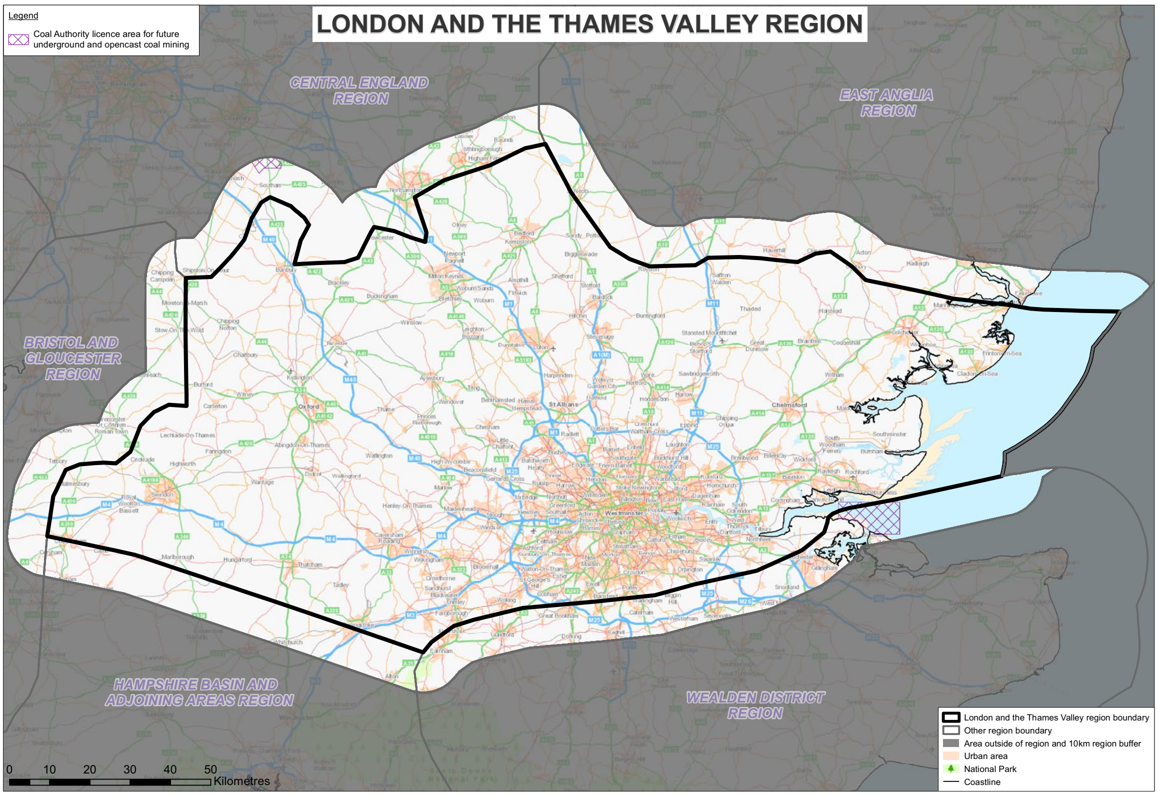


Figure 8c Areas of the London and the Thames Valley region with historical iron ore mines less than 100m deep.

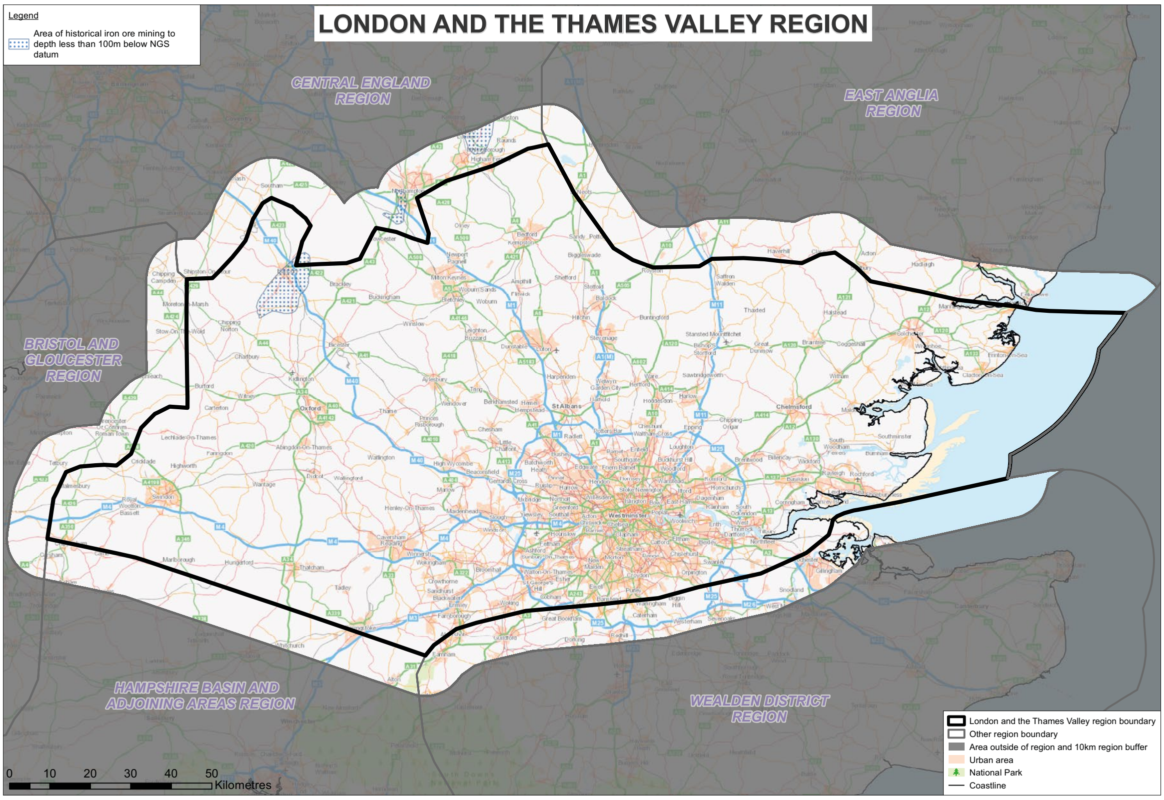
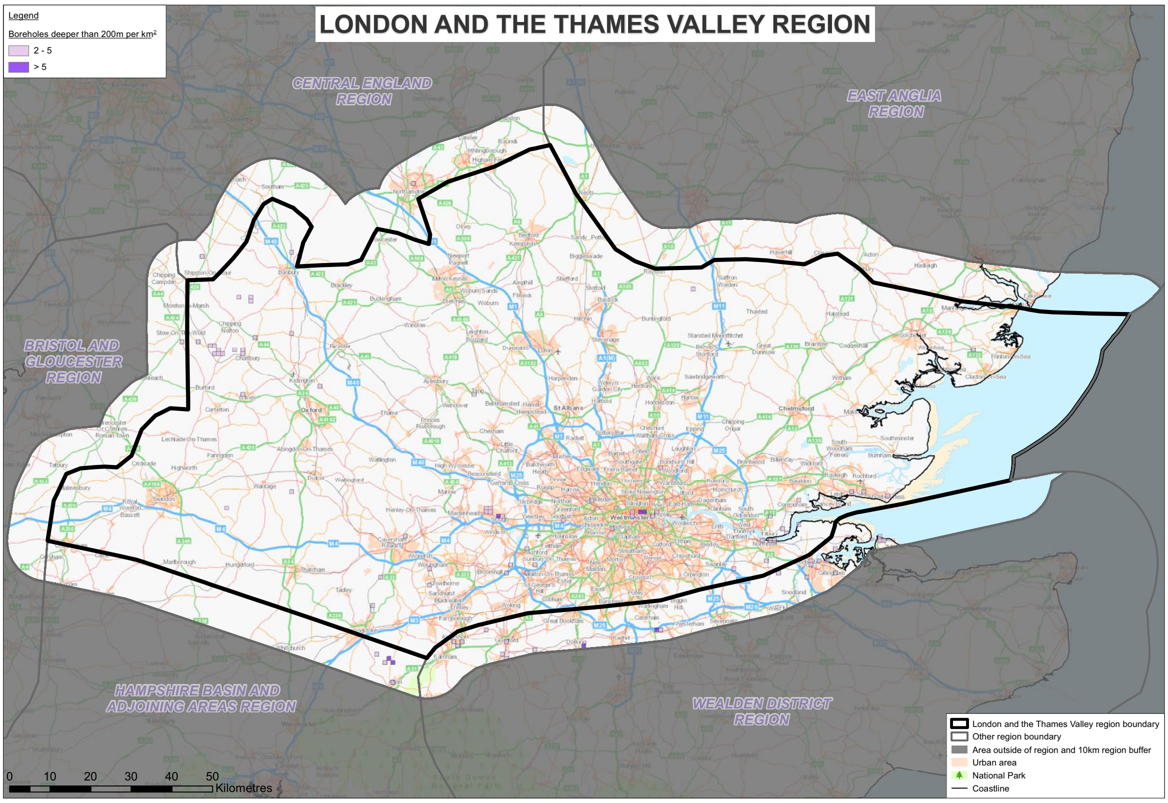


Figure 9 Areas in the London and the Thames Valley region with concentrations of deep exploration boreholes.



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 Glaciation
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

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.

Compacted
The action of squeezing as sediments become more deeply buried. Like wringing a sponge, compaction leads to loss of pore water and reduction of pore spaces between rock grains.

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.

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

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.

Lava flow
A mass of flowing or solidified lava. After cooling and solidification, lava flows often form distinctive topographical features.

Lithology
The physical properties of rock types

Metamorphosed
A rock that has undergone change due to the action of temperature and pressure.

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).

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.

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