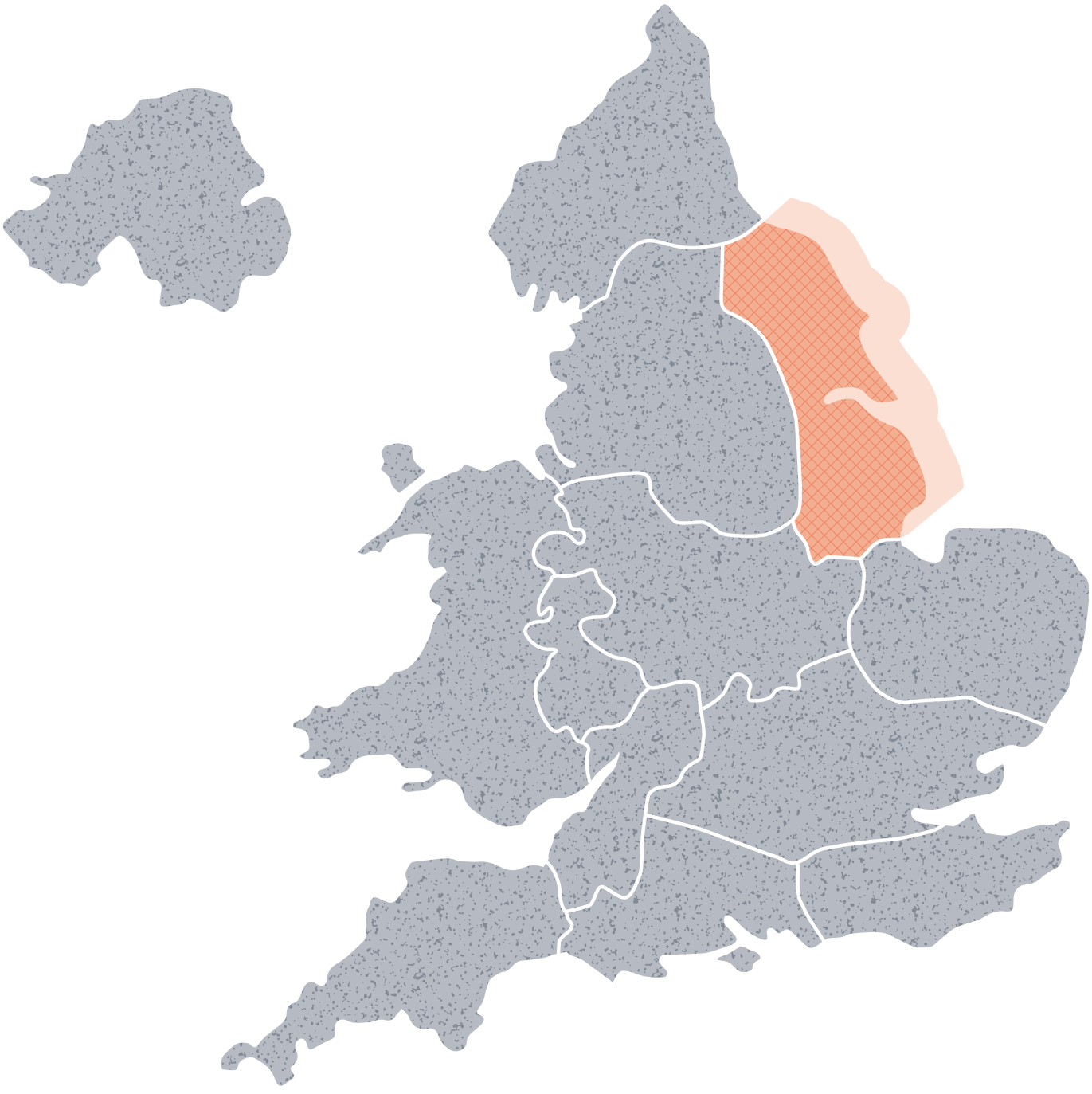
Radioactive Waste Management



Eastern 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 comprises most of the counties of Humberside and Lincolnshire and parts of Cleveland and Yorkshire. It includes the adjacent inshore area which extends up 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 4 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.

Eastern 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. The information comes from geological mapping, geophysical surveys and boreholes.

Available information for this region

There are more than 690 boreholes drilled to more than 1,000m depth in search of coal, oil and gas, water and mineral salts (evaporites). This information is also supplemented by extensive geophysical investigations including studies of the Earth's gravity and magnetic fields and seismic surveys. The distribution of rocks in this region is therefore reasonably well known at the national scale. There are a number of shallower boreholes that provide information on 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 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 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 in the region are glacial deposits, including sands, gravels and tills (boulder clays). These are well known because they are close to surface and have been sampled in many boreholes. However, as they do not occur below 200m they are not of relevance to the safety of a GDF and are not therefore discussed here.

Below these rocks a sequence of sedimentary rocks, of Cretaceous to Permian age (approx. 65 to 300 million years old, was laid down which includes limestones, sandstones, mudstones and evaporites. This includes Jurassic rocks (approx. 145 to 200 million years old), which are well exposed at the surface along the coast of the North York Moors in the north of the region. These deposits include a number of mudstones which occur underneath the whole region but reach their greatest thickness to the north of Market Weighton, in the Cleveland sedimentary basin. Rocks of late Jurassic to early Cretaceous age are not preserved in this region. Later Cretaceous rocks (approx. 65 to 145 million years ago), of the Speeton Clay Formation (north of Market Weighton) and the Tealby Formation (south of Market Weighton), and then Chalk Group, were laid down on a variety of the older Jurassic rocks.

There are several rock units in the younger sedimentary rock sequence which contain thick mudstone layers and are likely to behave as LSSR. Some of these occur at the surface in the north-eastern part of the region and all are well known from drilling across a large part of the region.

Older sedimentary rocks

Sedimentary rock layers of Carboniferous age (approx. 300 to 360 million years old) are present below the younger sedimentary rocks and are similar to rocks occurring at the surface to the west of the region. They include limestones, sandstones, shales and the Coal Measures, which are a continuation of the Yorkshire and East Midlands Coalfield. These rocks have been buried sufficiently deeply that they are now highly compacted.

The whole sequence of sedimentary rocks generally dips towards the east across the whole region (see Figure 5) and are underlain by basement rocks.

Basement rocks

The oldest rocks of the region are of Ordovician age or older (over approx. 445 million years old). These form the basement (shown in blue on Figure 4) to the sedimentary rocks that rest on top of them. Some of these basement rocks are potential HSR hosts. They are not exposed at the surface in this region, but some have been found in deep boreholes in the south of the region. They comprise two types of igneous rocks:

- andesite and dacite lavas, the result of volcanic activity in the Ordovician (approx. 445 to 485 million years old), found in a borehole near Grantham
- granitic rocks, formed from the solidification of molten rock below ancient volcanoes, found at 1,321m depth in a borehole near Horncastle but thought to be within the depth range of interest near Boston, based upon geophysical data

The BGS considers that these igneous rocks are potential HSR host rocks. Given the current lack of detailed information on basement rocks in general in this region, considerable further investigation would be required to determine their suitability.

Rock structure

The Rock Types of Interest within the depth range of interest have not been folded on a scale that would affect the siting of a GDF. However, the basement rocks occurring at depth in the south of the region were folded before the older sedimentary rocks were deposited on top of them.

The small number of major faults in this region is shown in Figure 7. There are 2 main areas of major faulting. The first is in the south of the region where several major faults affect the deeper basement rocks. These faults are widely spaced (generally more than 10km apart) and although they do not generally reach the surface they have had an influence on the thicknesses of sedimentary rocks deposited on top of the basement rocks in this area. The second is a set of faults that are curved in plan view and are aligned east to west between Scarborough and Bridlington in the east, and Thirsk and York in the west. These faults are part of the 175km long North Craven-Vale of Pickering-Flamborough Head Fault Zone which forms the boundary between the Cleveland Basin to the north and the Market Weighton Block to the south.

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 the Chalk Group, various Jurassic limestones and sandstones such as the Lincolnshire Limestone Formation, the Sherwood Sandstone Group and limestones and sandstones in the Permian Zechstein and Rotliegend Groups. Groundwater contained in these aquifers is likely to be separated from the groundwater in other aquifers and rocks at greater depth by low permeability LSSR layers between them, although this may not be the case where the Chalk aquifer rests directly on some of the older Jurassic aquifers. Groundwater from the shallow parts of a number of these aquifers (up to 200m depth) is used for public water supply and industry. However, there is considerable evidence that as these rocks become deeper to the east, and are confined by the overlying layers of mudstone, the groundwater becomes increasingly saline. For the most part these saline waters are interpreted by hydrogeologists as palaeowaters, remnants of former groundwater conditions which are largely unaffected by the current circulation of fresh water nearer to the surface.

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

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

Resources

A wide range of resources have been exploited in the Eastern England region. The locations of iron ore mines extending below 100m are shown in Figure 8a. The locations of coal mines extending below 100m and Coal Authority Licence Areas are shown in Figure 8b. The locations of hydrocarbon fields and areas licensed for potential development are shown in Figure 8c. Areas of historic iron ore mining shallower than 100m and evaporite mines extending below 100m are shown in Figure 8d. These include oil and gas fields around Gainsborough, Louth, Whitby and Malton, potash mining at Boulby near Middlesbrough and gas storage facilities near Saltfleetby, just north of Mablethorpe, and Hornsea.

Petroleum Exploration and Development Licences[2] for conventional hydrocarbons have been granted for areas to the north and south of the Humber (Figure 8c). The Vale of Pickering and a smaller area to the north-west of Lincoln have also been identified as prospective shale gas areas.

Although there are deep (up to 1,000m in depth) and very deep (over 1,000m in depth) coal resources underlying most of the region, there are no current licences to exploit these resources.

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. Eastern England is a region of relatively low seismicity. Earthquakes are seldom large enough to be felt and the ground surface is not known to have been broken by active faults. The largest measured onshore earthquake since 1970 had a magnitude of 4.9Mw and occurred near Market Rasen on 29 February 2008. The earthquake caused only superficial damage near the epicentre, probably on account of the great depth of the earthquake focus (18km). Seismicity off the coast includes the 5.9Mw Dogger Bank earthquake of 1931, the largest recorded earthquake in Britain, with an epicentre around 120km east of Flamborough Head.

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 several lowland and continental-scale glaciations during the last two and a half million years (including the Anglian and Late Devensian Glaciations). It is widely accepted that the region is situated beyond the limits of highland-scale glaciations. Therefore 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 along the eastern edge 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 future 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 Eastern England region as defined for the purpose of National Geological Screening.

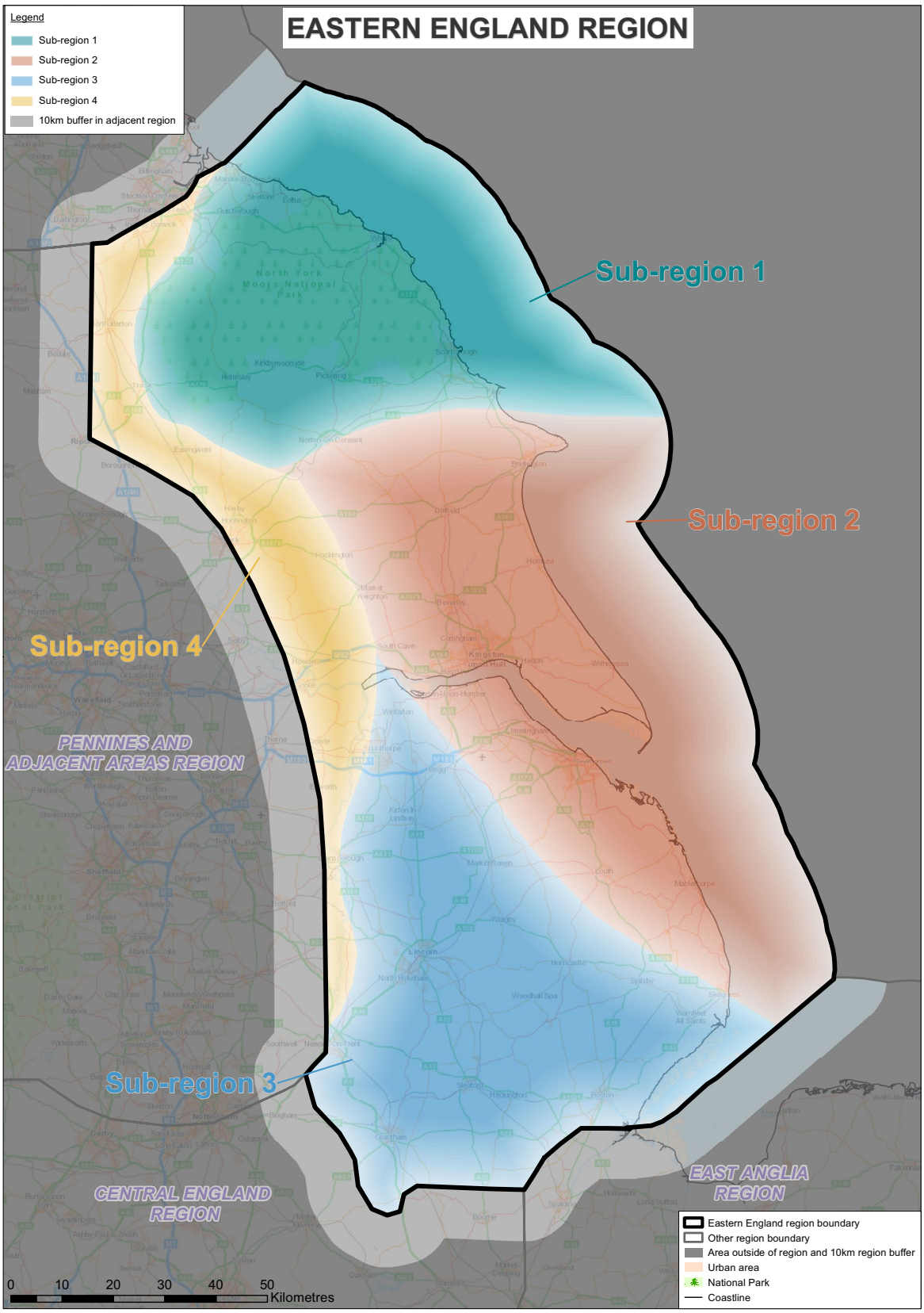


Figure 2 Table illustrating the sequence of the major rock units present in the Eastern England region and their possible significance for the siting of a GDF[3].

	Geological Period (age in millions of years)	Geological Unit	Dominant Lithology	Rock types of interest		
				LSSR	HSR	Evaporite
Younger sedimentary rocks	Cretaceous (66.0 – 145.0)	Chalk Group	Chalk			
		Tealby Formation (N) Speeton Clay Formation (S)	mudstone and sandstone	✓		
	Jurassic (145.0 – 201.3)	Ancholme Group including Kimmeridge Clay, Ampthill Clay, West Walton and Oxford Clay Formations	mudstone, siltstone, limestone and sandstone	✓		
		Corallian Group	limestone, sandstone and mudstone			
		Ravenscar Group	sandstone, siltstone and mudstone	✓		
		Great Oolite Group	sandstone and limestone with mudstone			
		Inferior Oolite Group	limestone, sandstone, mudstone			
		Lias Group	Mudstone with limestone and sandstone	✓		
	Triassic (201.3 – 251.9)	Penarth Group	mudstone, siltstone and sandstone	✓		
		Mercia Mudstone Group	mudstone with siltstone and evaporite (anhydrite, gypsum and rock salt)	✓		✓
		Sherwood Sandstone Group	sandstone with conglomerate and mudstone			
	Permian (251.9 – 298.9)	Zechstein Group	limestone and mudstone with evaporite			✓
		Rotliegendes Group	sandstone			
Older sedimentary rocks	Carboniferous (298.9 – 358.9)	Warwickshire Group	sandstone and mudstone	✓		
		Pennine Coal Measures Group	mudstone, siltstone, sandstone and coal			
		Millstone Grit, Yoredale and Craven Groups	sandstone, siltstone, limestone, mudstone and coal			
		Carboniferous Limestone Supergroup (Dinantian Rocks -Undifferentiated)	limestone			
Basement	Ordovician (443.8 – 485.4)	Ordovician Rocks, (Undifferentiated)	andesite and dacite lavas		✓	
	Lower Palaeozoic Rocks (older than 485.4)	Undivided	granitic rocks		✓	

[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 Eastern 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.

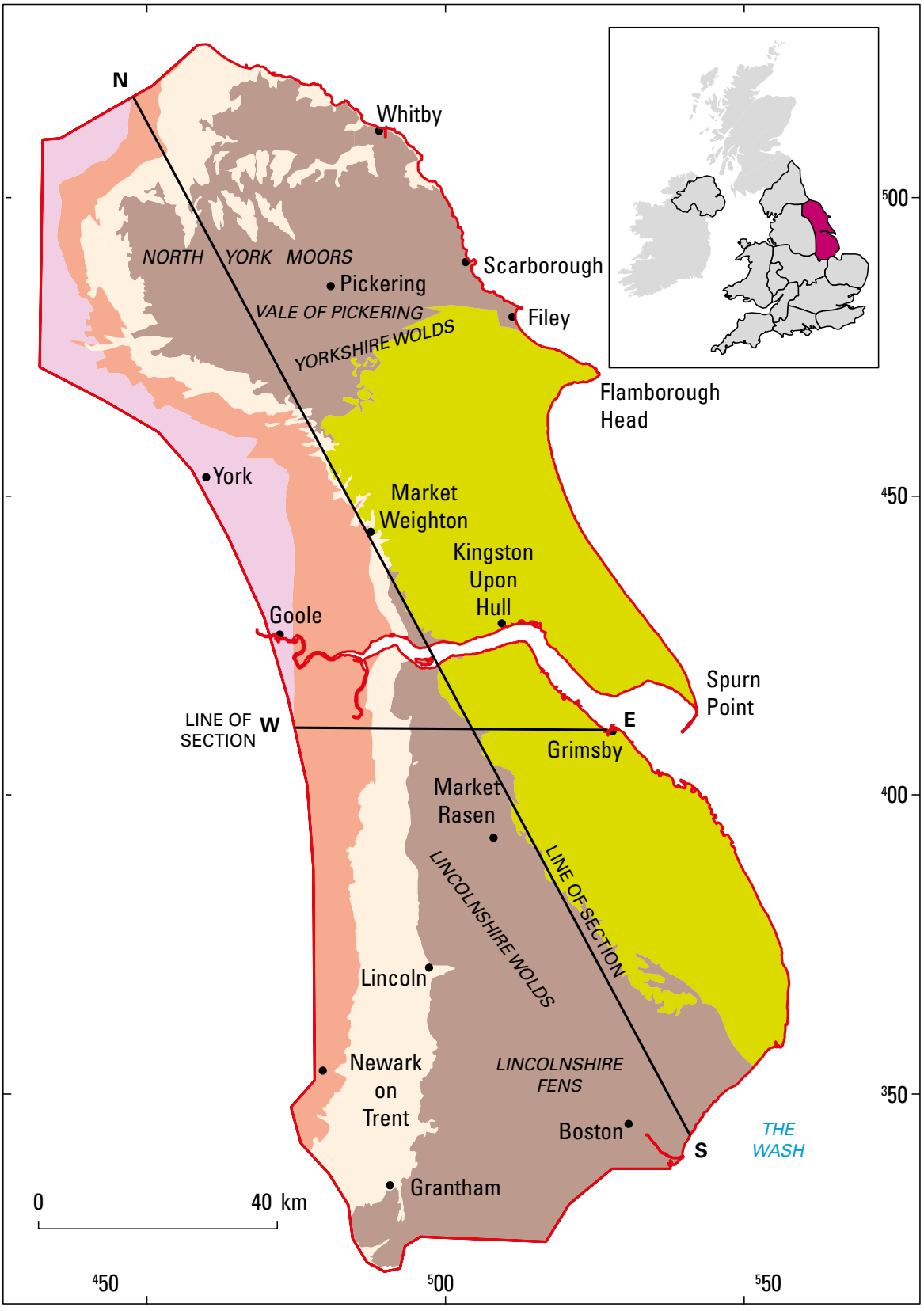


Figure 4 Schematic cross-section north to south through the Eastern England region. Line of section is shown in Figure 3. Note that the vertical scale is greatly exaggerated and actual dips of rock layers are much gentler than they appear here. See Figure 2 for the key to the rock types shown.

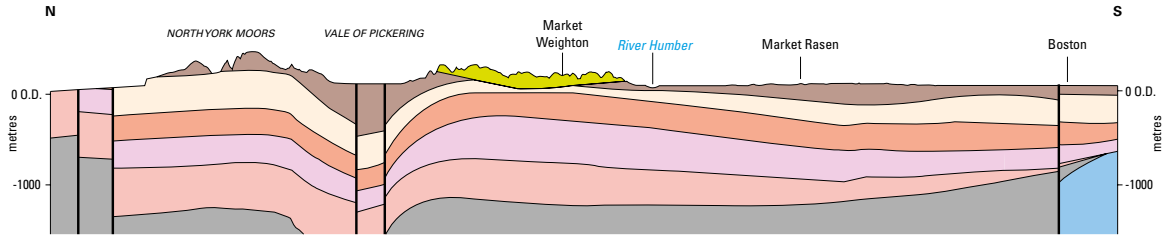


Figure 5 Schematic-cross section west to east through the Eastern England region. Line of section is shown in Figure 3. Note that the vertical scale is greatly exaggerated and actual dips of rock layers are much gentler than they appear here. See Figure 2 for the key to the rock types shown.

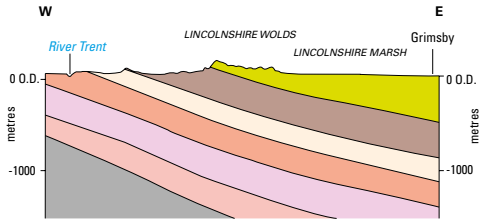


Figure 6a The areas of the Eastern England region where any of the 3 Rock Types of Interest are present between 200 and 1,000 m below NGS datum.

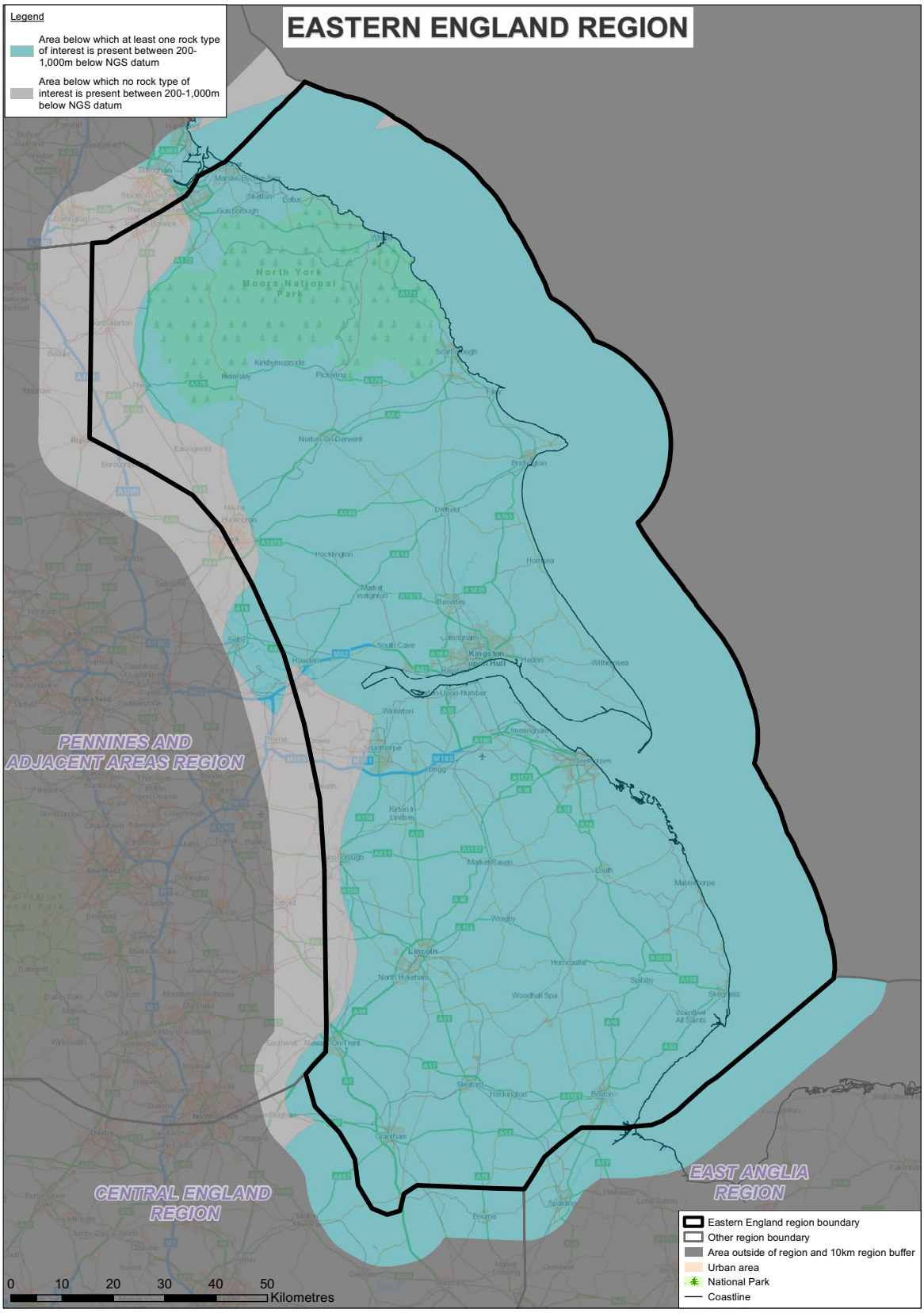


Figure 6b The areas of the Eastern England region where Lower Strength Sedimentary Rock Types of Interest are present between 200 and 1,000 m below NGS datum.

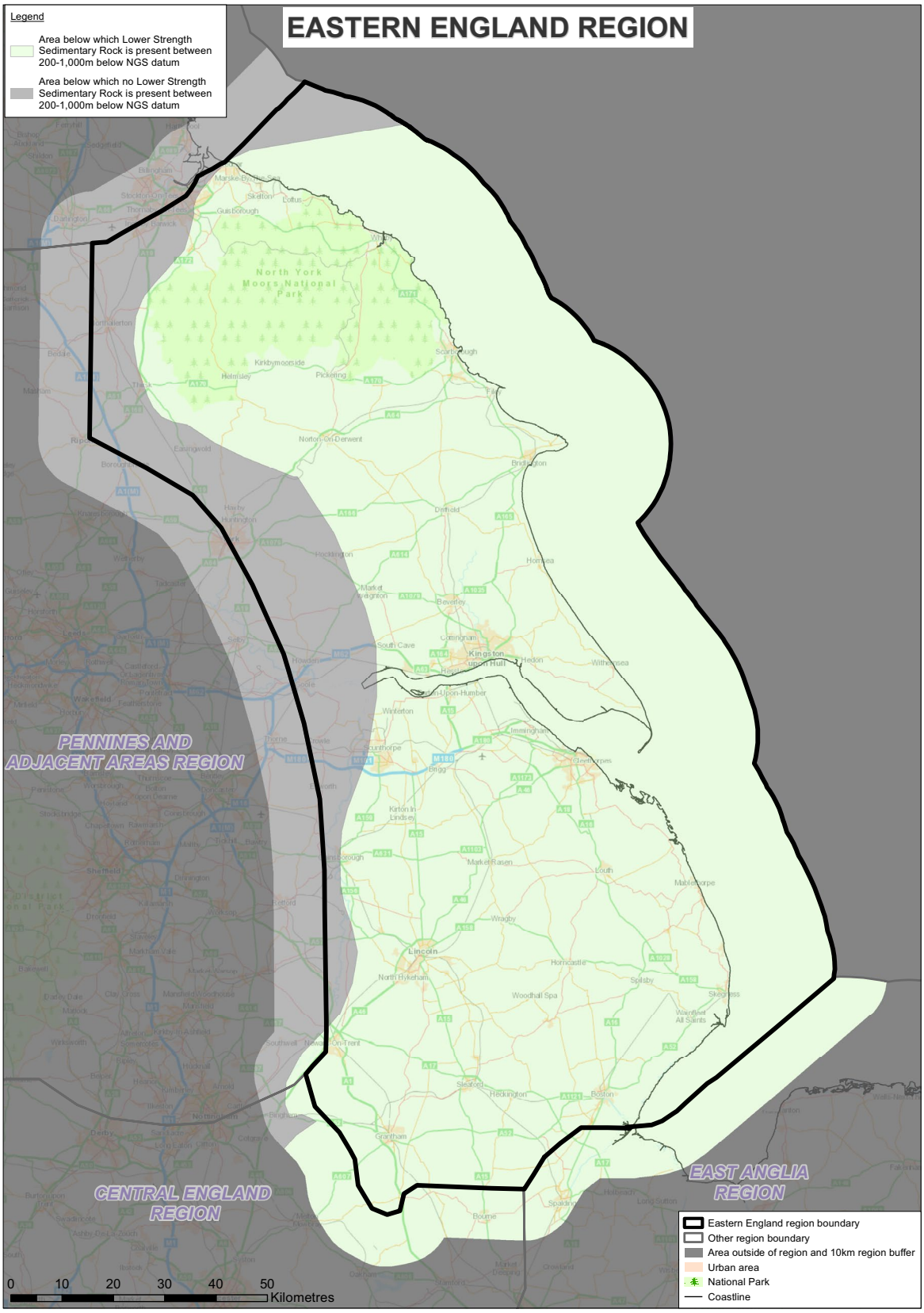


Figure 6c The areas of the Eastern England region where Higher Strength Rock Types of Interest are present between 200 and 1,000 m below NGS datum.

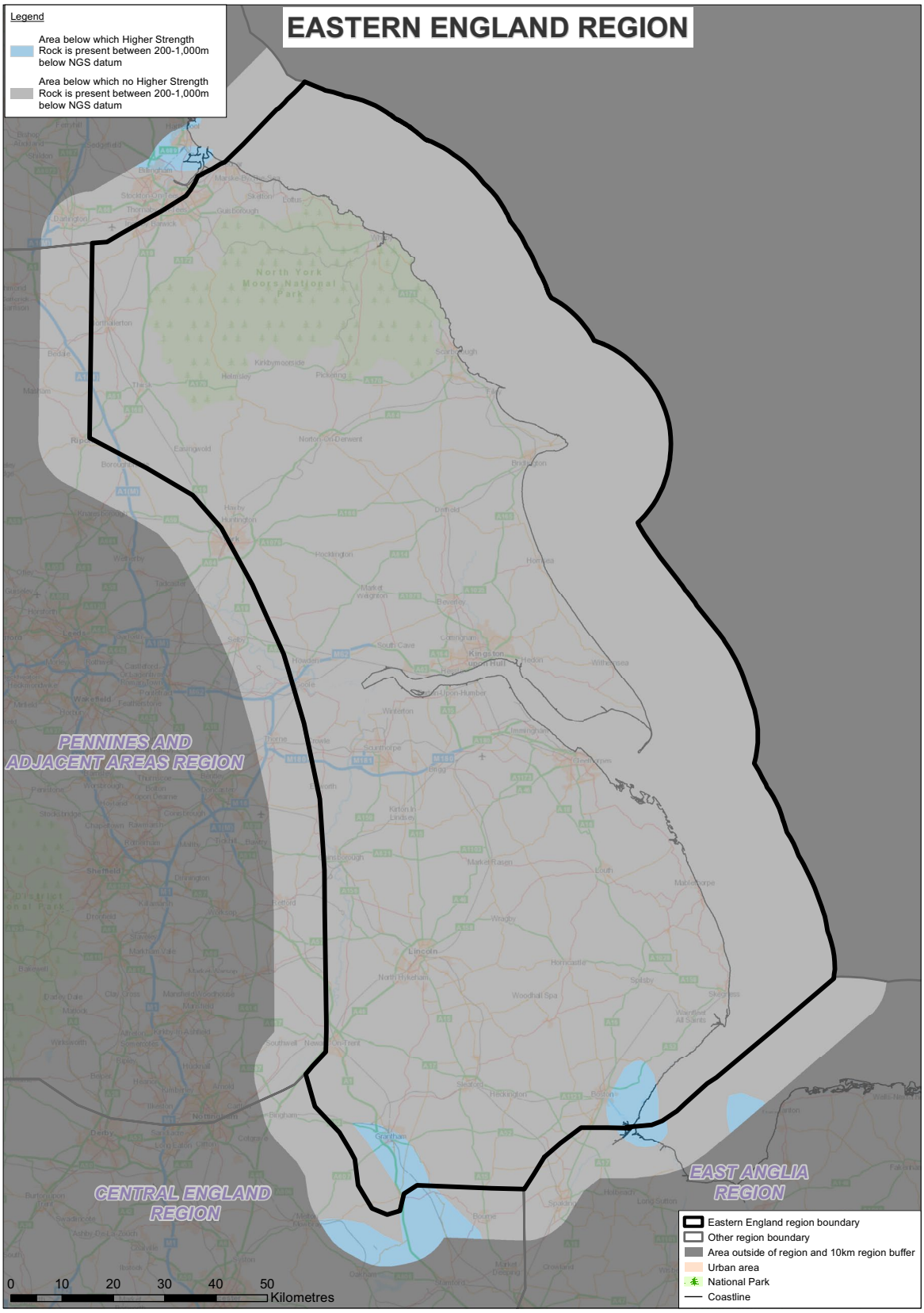


Figure 6d The areas of the Eastern England region where Evaporite Rock Types of Interest are present between 200 and 1,000 m below NGS datum.

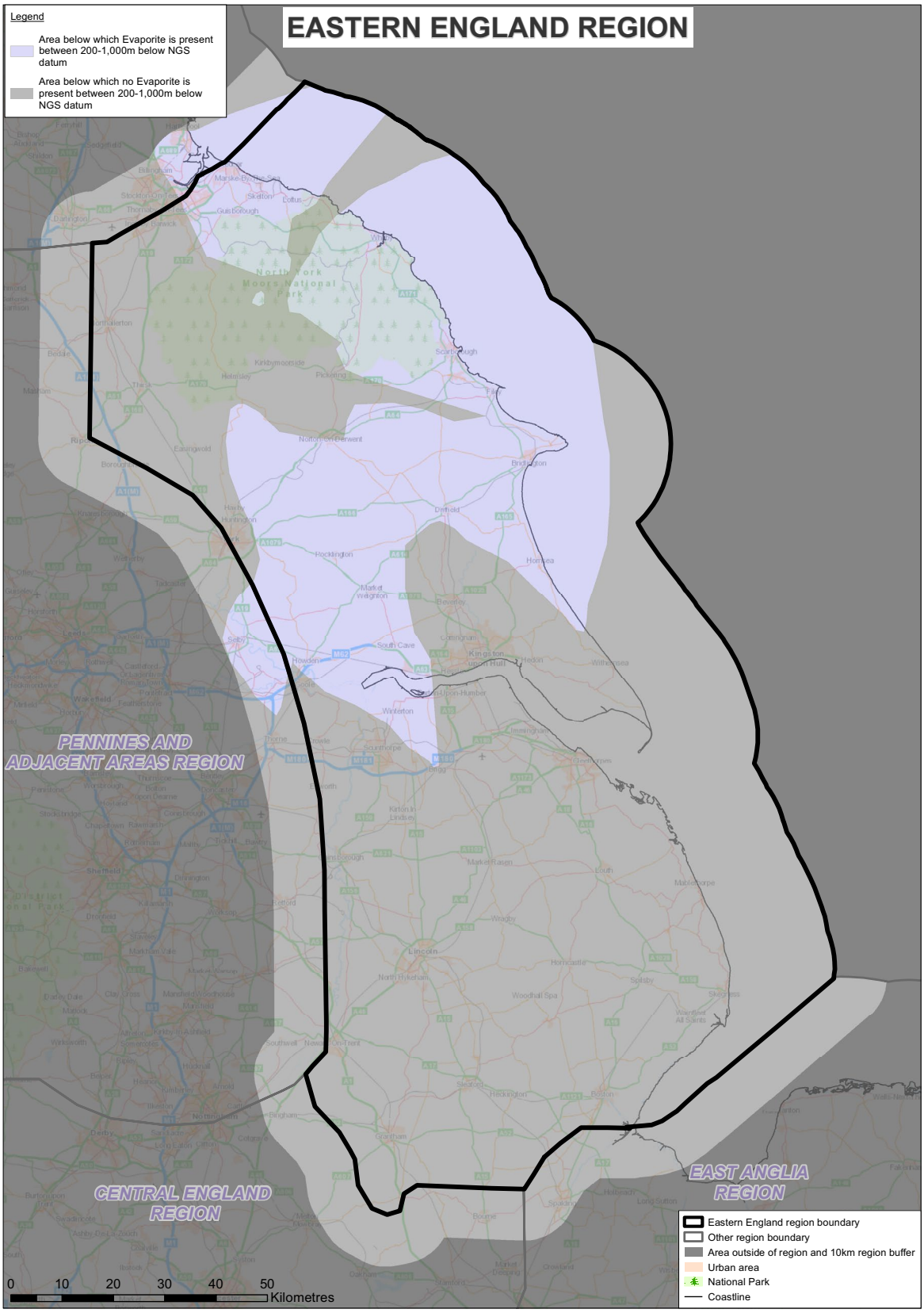


Figure 7 Location of major faults in the Eastern England region.

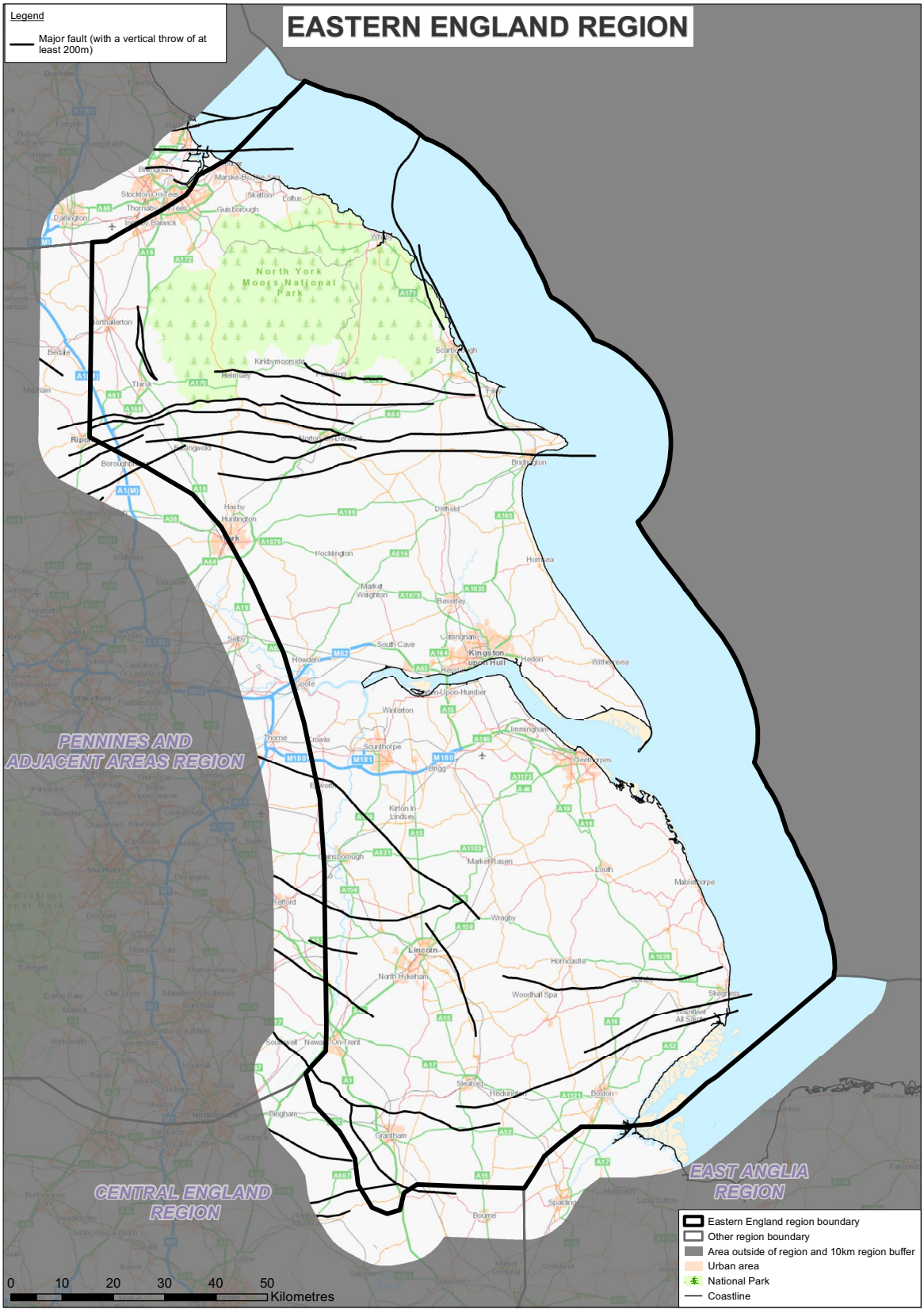


Figure 8a Areas of the Eastern England region with iron ore mines present below 100m.

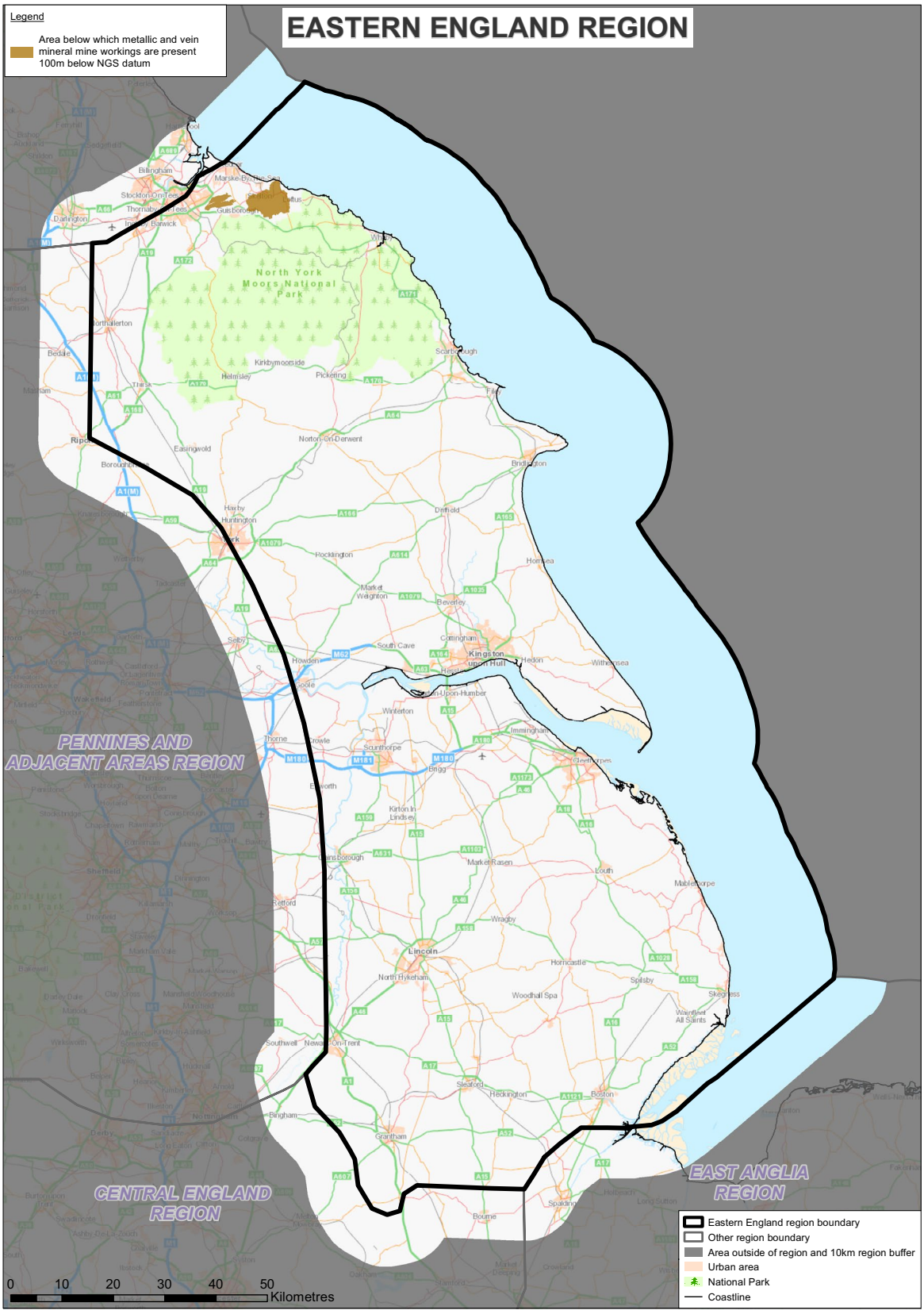


Figure 8b Areas of the Eastern England region with coal mines present below 100m and Coal Authority Licence Areas.

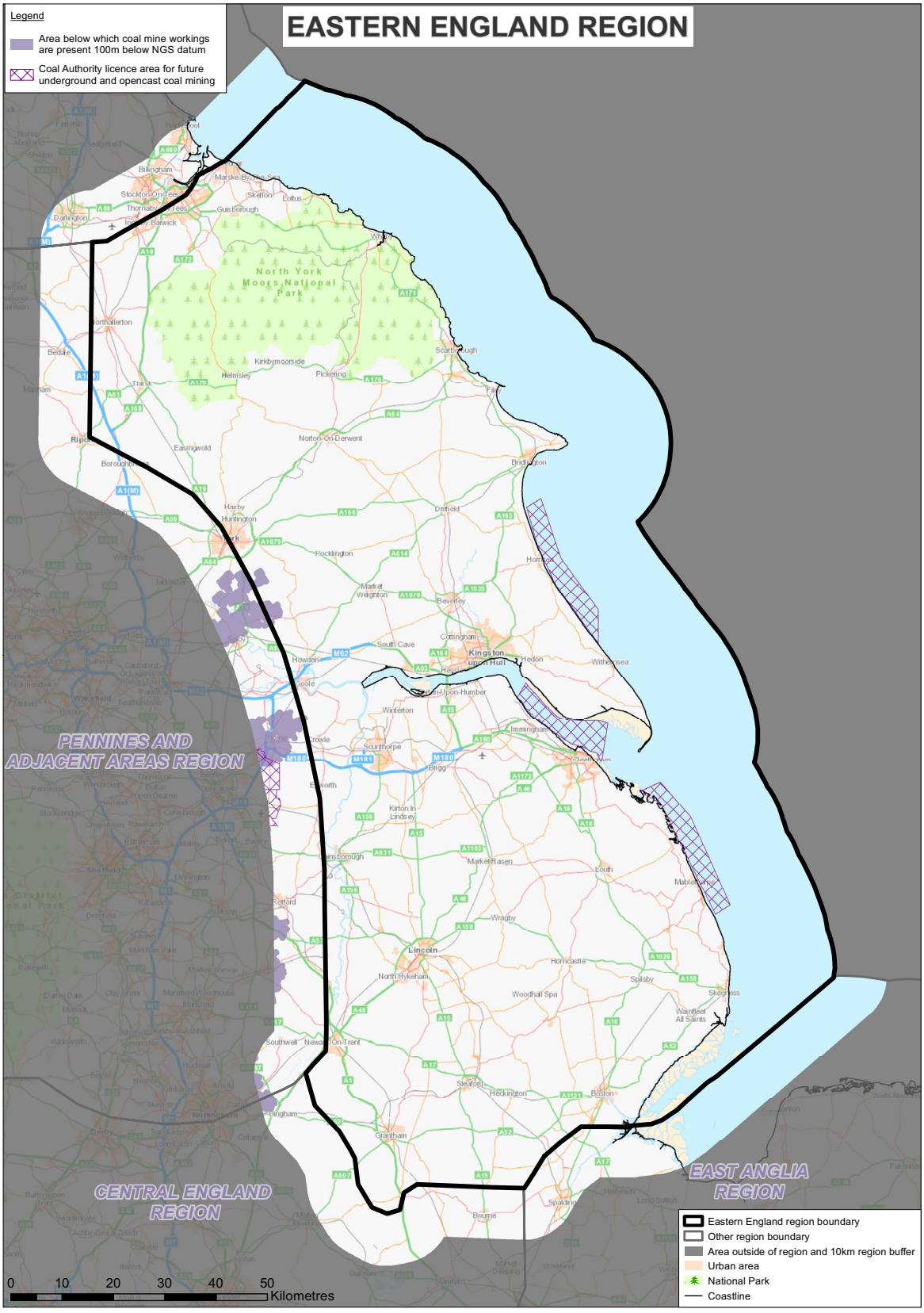


Figure 8c Areas of the Eastern England region with oil and gas fields and Petroleum Exploration and Development Licences.

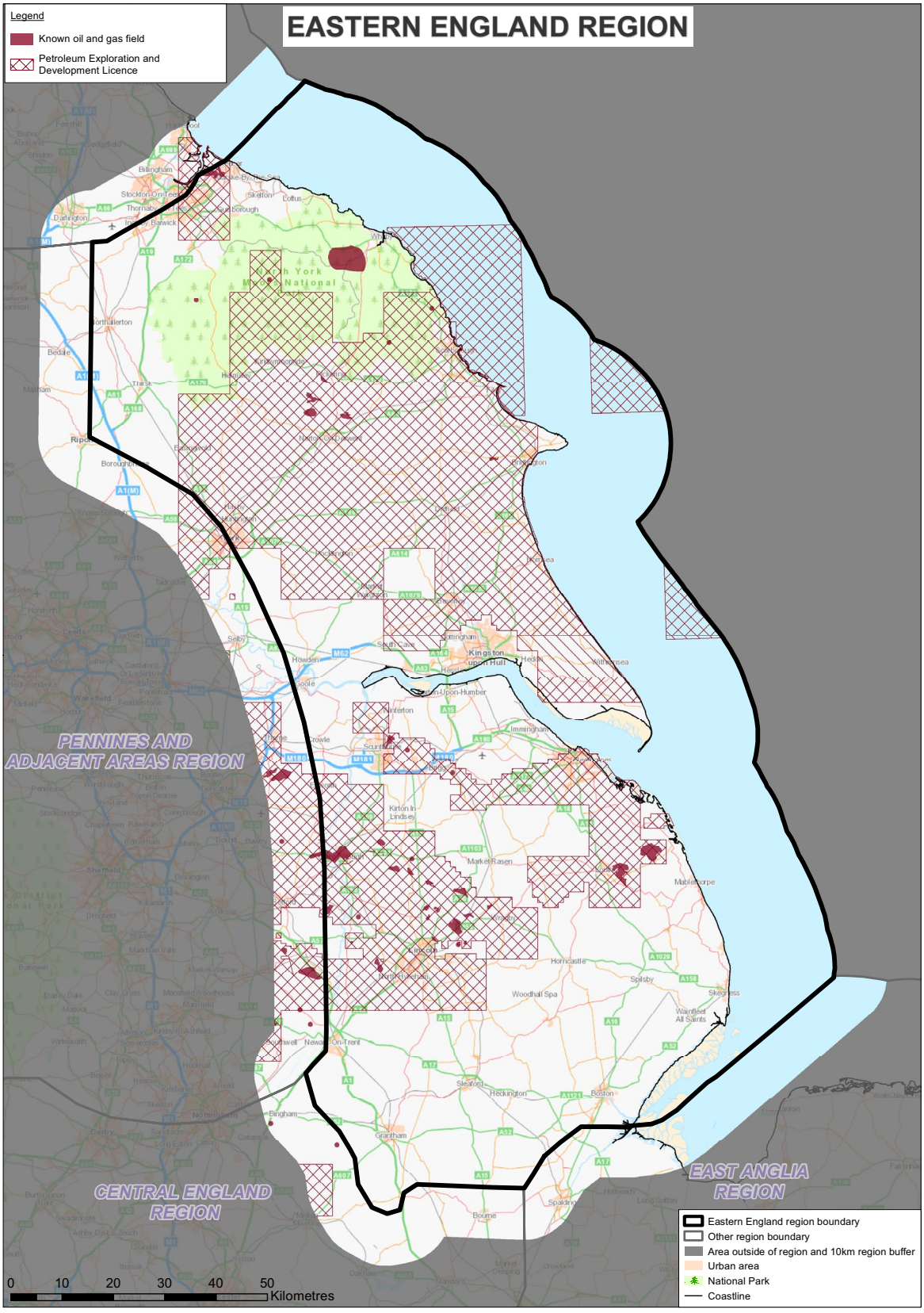


Figure 8d Areas of the Eastern England region with historical iron ore mines less than 100m deep and evaporite mines present below 100m.

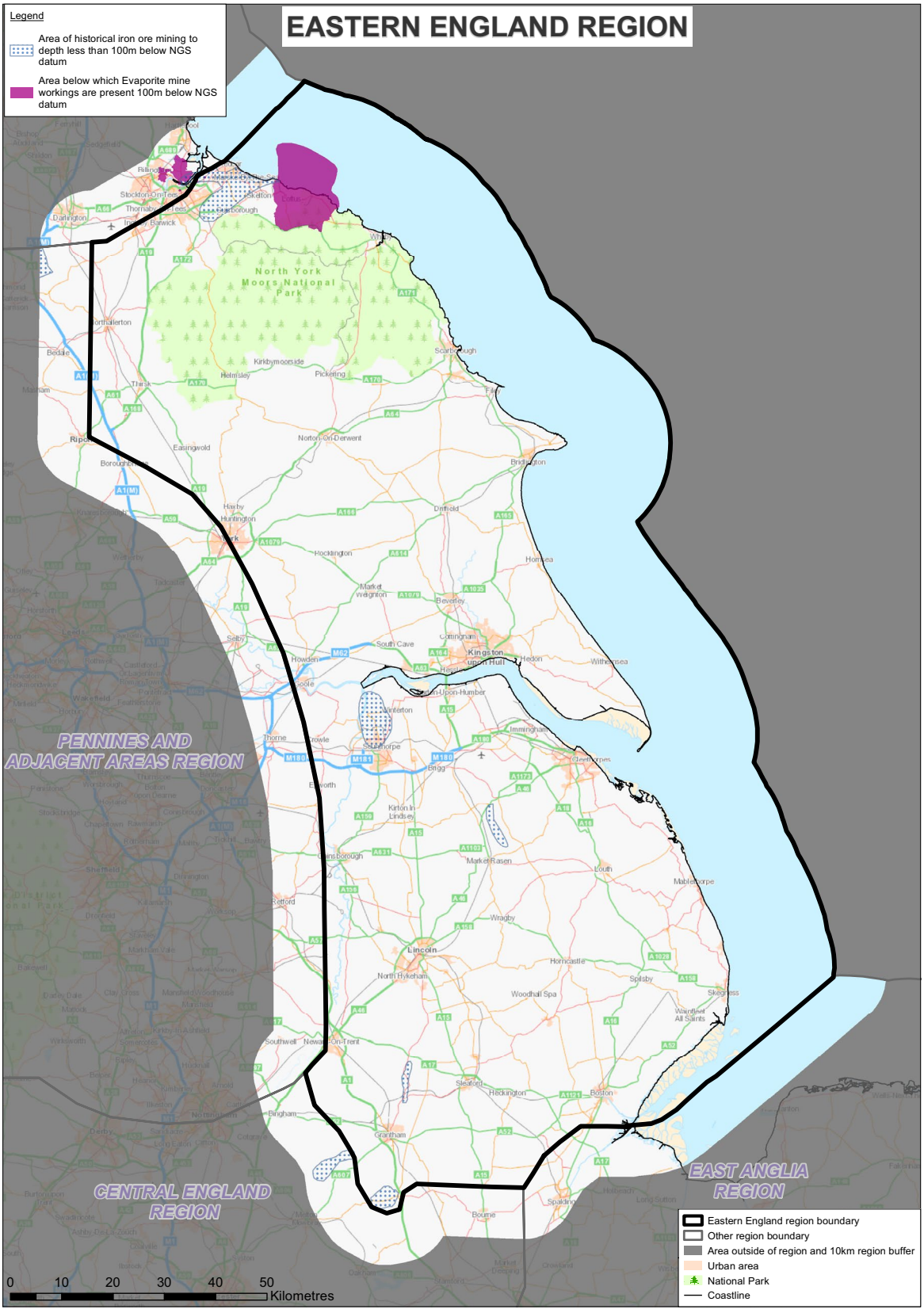
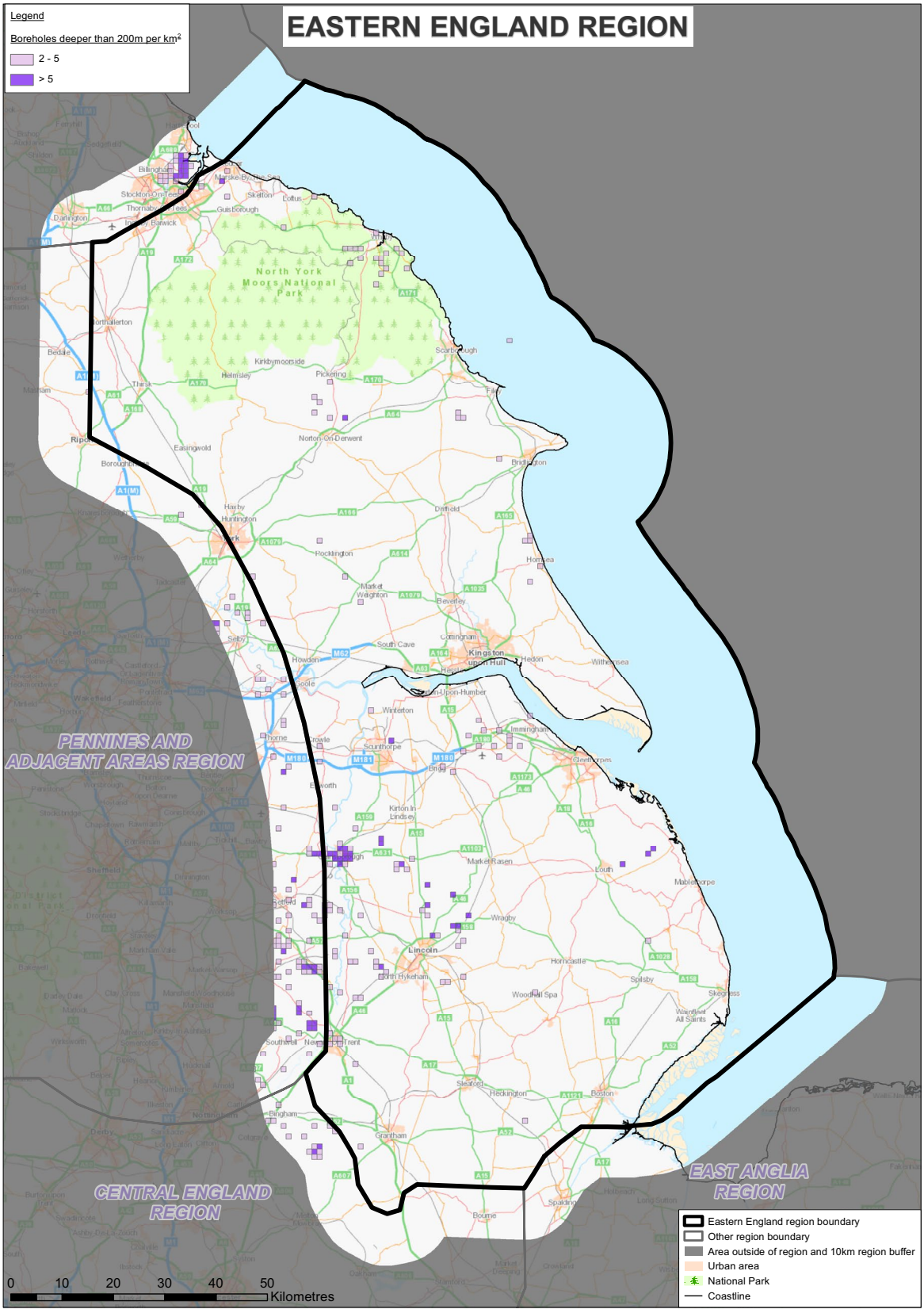


Figure 9 Areas in the Eastern England region with concentrations of deep exploration boreholes.



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.

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.

Conventional hydrocarbon
Underground petroleum products (i.e. oil & gas), trapped in high-permeability reservoir rocks, that are extracted using well-established methods that are commonplace in the oil, gas and mining industries.

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.

Epicentre
The point on the surface of the Earth above the focus of an earthquake. The hypocentre of an earthquake is the point underground where the earthquake occurs.

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
The generic term for rock created by the evaporation of water from a salt-bearing solution, such as seawater, to form a solid crystalline structure. Gypsum, anhydrite and halite are all types of evaporite.

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

Glacial deposits
Sedimentary rocks that have been deposited by the action of melting glacier ice. These deposits are characterised by their assortment of different compositions and clast sizes. Glacial deposits are widespread near the surface due to relatively recent (in geological time) glaciations.

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

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.

Lavas
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.

Palaeowaters
An ancient body of water that has been contained in an undisturbed space, such as a confined aquifer. Also called fossil water.

Potable
Water that is of drinkable quality.

Potash
The collective term for potassium-bearing evaporite minerals. Potash is mined in the UK for use in fertilizer.

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 survey
Geophysical method that produces an image of the subsurface by transmitting shock waves, or seismic energy, into the ground and measuring the pattern of energy that is reflected back to the surface. Widely used by the resource industries to provide information on the composition and structure of the underground geology.

Shales
A very fine-grained and strongly layered sedimentary rock in which the grains are not visible to the naked eye. Consists of clay grains and tiny fragments of other minerals such as quartz and mica.

Shale gas
Gas that is naturally generated and trapped within shales that contain a high amount of organic material. Shale gas can be extracted for use as a fuel in heating or power generation by a technique known as hydraulic fracturing or 'fracking'.

Tills
Sediments that are made up of a range of different sized materials ranging from large boulders and pebbles to very fine mud and clay. Tills are deposited directly by glaciers which erode and entrain rocks by the movement of the ice. Tills are a common surface deposit in the UK in areas that were subjected to glaciation.

Radioactive Waste Management

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