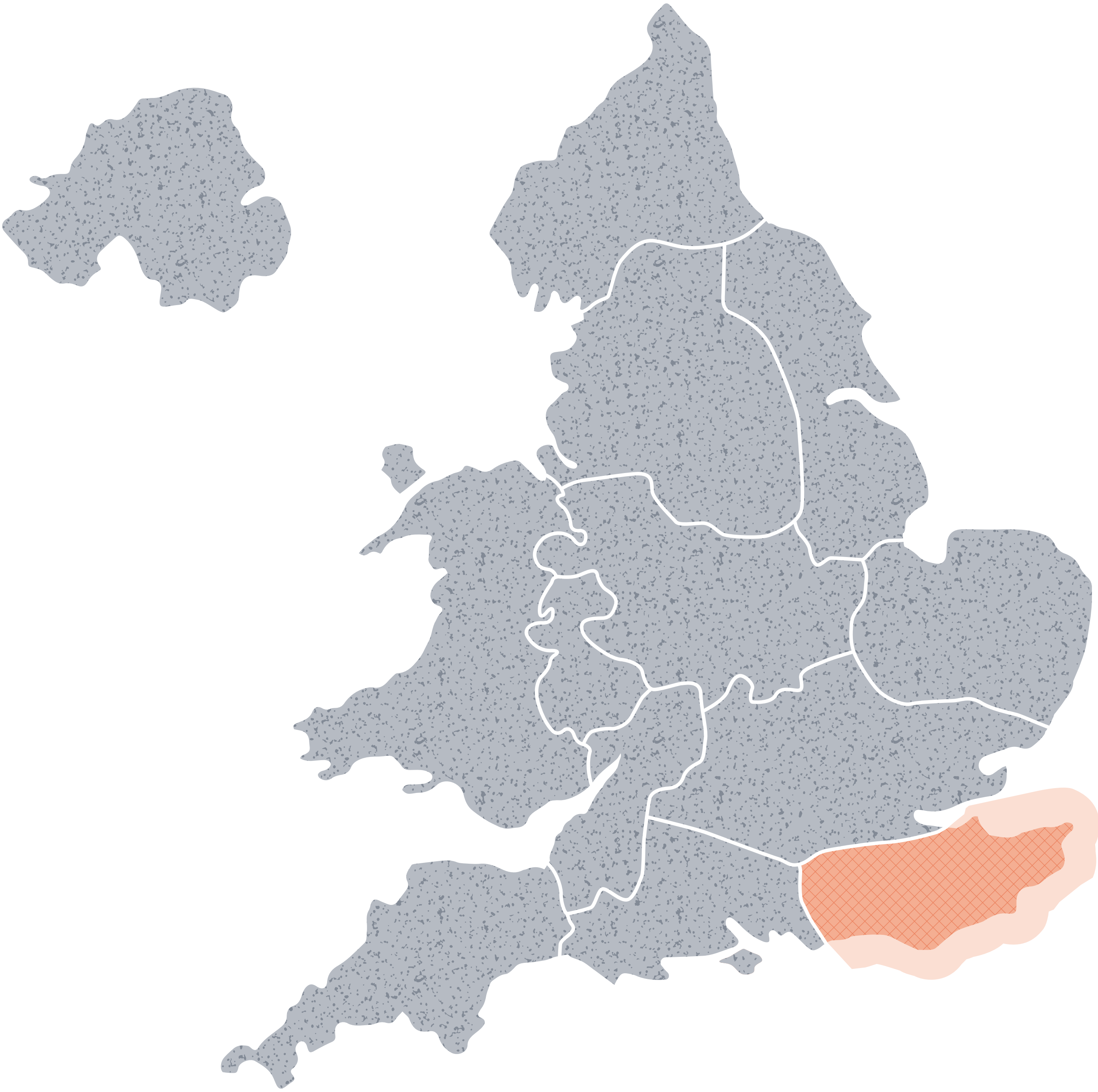
Radioactive Waste Management



Wealden District

REGIONAL GEOLOGY

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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 includes the whole of East Sussex, most of Kent and West Sussex, the southern half of Surrey and a small part of eastern Hampshire. It includes 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 2 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.

Wealden District: 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. Information about the geology of the region comes from geological mapping, geophysical surveys and boreholes.

Available information for this region

Geological mapping of the area is informed by rock exposures in the extensive coastal cliffs and in man-made excavations such as quarries or road cuttings. There are about 200 boreholes drilled to more than 150m depth in search of water, coal, oil and gas, and gypsum in various parts of the region, of which about half are more than 1,000m deep. Most are in either the central or western parts of the region, where prospects for oil and gas are most promising, or in east Kent within the area of the coalfield. This information is supplemented by geophysical investigations including studies of the Earth's gravity and magnetic fields and a closely-spaced network of exploration seismic survey lines covering most of the region except for parts of the extreme north-east. The amount of information available means that the types of rock present in the depth range of interest are reasonably well known. 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, older sedimentary, 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 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.

The youngest rocks in the region, such as the London Clay, Woolwich and Reading Beds and Thanet Sand Formations, are well known because they are close to the 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.

Younger sedimentary rocks

The youngest of the 3 main groups of rocks comprises a sequence of sedimentary rocks known to include sediments deposited between approximately 65 and 300 million years ago and including mudstones, limestones and sandstones. The sediments were deposited in a broad depression known as the Weald Basin centred on the Ashdown Forest area, near Wych Cross. Following a break in deposition, referred to as an unconformity, the sea level started rising again during the Upper Cretaceous (approx. 65 to 100 million years ago) and the Gault Clay Formation and then the Chalk Group were laid down on a variety of older rocks. A later period of uplift resulted in younger rocks in the middle of the basin being removed by erosion to expose the older rocks below. As a result, the youngest rocks such as the Chalk occur in a ring around the southern, western and northern margins of the region including the North and South Downs (see Figure 3).

There are several rock units in the younger sedimentary rock sequence that contain thick, extensive mudstone layers and are likely to behave as LSSR. These rocks are well known from drilling across a large part of the region. The Wealden Group, Gault, Kimmeridge and Oxford Clay Formations and the Lias and Mercia Mudstone Groups are all in excess of 50m thick over part of the region, and are therefore potential LSSR host rocks. Within the depth range of interest, the younger Wealden Group occurs in the west and centre of the region while the Upper Jurassic mudstones (Kimmeridge and Oxford Clay Formations) occur in the centre and south of the region. The older Lias and Mercia Mudstone Groups occur only towards the bottom of the depth range of interest in the east of the region. The Gault Clay Formation is present in the depth range of interest only towards the margins of the region, in north Kent and Surrey and in Sussex and immediately adjacent parts of Hampshire. In addition to these thicker mudstones there are several other mudstone layers in the younger sedimentary rock sequence as shown in Figure 2.

Although the Mercia Mudstone Group is known to contain some rock salt (halite) layers under this region, they occur below the depth range of interest.

Older sedimentary rocks

Sedimentary rocks of Carboniferous to Devonian age (approx. 300 to 420 million years old) are known to occur below most of the region but only occur within the depth range of interest in the north-east. These are referred to here as older sedimentary rocks and include limestones, sandstones, mudstones and, in the Kent Coalfield, coal seams. They have been buried sufficiently deep such that they are now harder and more compacted than the younger sedimentary rocks above.

The BGS has identified one of these older sedimentary rock layers, the Warwickshire Group, as a potential LSSR host rock. However, although it does contain some mudstones, they are interbedded with sandstones and 6 main coal seams, which have been mined. The Warwickshire Group therefore has less potential to be a LSSR host rock in this region.

Basement rocks

The oldest group of rocks in the region is of Silurian age or older (over approx. 420 million years old)[1] . These form the basement to the sedimentary rocks that lie above. Basement rocks are not exposed at the surface in this region, but their nature can be inferred from similar rocks occurring at the surface in other regions, such as Central England and the Welsh Borderlands. Basement rock has been found in deep boreholes across the region, but only occurs within the depth range of interest in the north and east. In the area between Maidstone, Folkestone and Hastings and extending into the inshore, the basement comprises predominantly mudstones and siltstones which may have developed a cleavage during the Variscan mountain building period and the BGS consider it may be a potential HSR host rock. There is insufficient information available at present to know whether these rocks would be suitable to host a GDF.

[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 the 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.

Rock structure

The region is dominated by the Weald Anticline, a broad arch-like fold aligned roughly west-north-west to east-south-east (WNW-ESE) that formed in response to compressive tectonic forces related to the formation of the Alps some 20 million years ago. The Weald Anticline is cross-cut by discrete zones of faulting, generally aligned in an east-west direction, separated by less deformed areas (see Figure 7). These fault zones were active during the deposition of the Cretaceous and Jurassic sediments (approx. 65 to 200 million years ago) and they influence the local thickness variations of many of the LSSR Rock Types of Interest. They are related to deep-rooted fault structures which originally formed in the underlying basement rocks during the collision of tectonic plates 280 to 380 million years ago.

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.

In a few places, Alpine compressive forces caused reversal of movement on the Jurassic and Cretaceous fault zones leading to uplifted ridges and steeply dipping rock layers. A good example is the Hog's Back monocline near Guildford (A on Figure 7).

A zone of rock deformation, the Variscan Front, extending eastwards from south-west England and south Wales, defines the northern boundary of the region before swinging south-eastwards through the Maidstone to Ashford areas, crossing the Channel coast near Folkestone. It is relevant because the nature of basement rocks is different to the north and south of the Variscan Front and may influence their suitability to host a GDF.

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 the Upper and Lower Greensand and Portland Stone Formations. These are some of the younger rocks, occurring only around the margins of the region. Groundwater contained in these aquifers is likely to be separated from the groundwater in other aquifers and rocks at greater depth by the low permeability LSSR layers between them, even where these layers are not thick enough to host a GDF. The Great and Inferior Oolite Groups and Carboniferous Limestone aquifer are all present at depths greater than 400m in this region. In some other regions these rocks occur at shallow depths and are principal aquifers. Groundwater from these aquifers in this region has not been sampled but it is likely to be old saline water rather than potable water as these rocks are not directly connected to the surface, and therefore not recharged by rainfall. Groundwater from depths greater than 400m is unlikely to be suitable as drinking water anywhere in the UK[2].

Mining is likely to have changed the original patterns of water movement in the eastern part of the region and shallower groundwater may now circulate to greater depths within the depth range of interest than it did before mining.

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

Resources

Coal has been mined from the Coal Measures at depths greater than 100m below NGS datum in east Kent (see Figure 8a). The coal is concealed entirely beneath a cover of younger rocks at depths between 300 to 1,500m and not all of the coal has been exploited with coal seams remaining in situ at depths less than 500m. Exploitation of this coalfield has now ceased.

There are several onshore oil fields in the region - 8 gas fields in the north and centre of the region and 7 oil fields (Figure 8b). Currently all 7 oil wells are producing but only one well actively produces gas, at Albury near Guildford.

A number of Petroleum Exploration and Development Licences[3] are currently held in the west of the region (see Figure 8b). Parts of the region contain mudstones or shales that have been identified as having potential for shale oil and/or shale gas. There are also Coal Authority Licence Areas associated with the Kent Coalfield and in the inshore to the north of Sheppey (Figure 8a)

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

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

Gypsum is mined at depths greater than 100m below NGS datum in the Brightling and Robertsbridge areas of east Sussex, just north of Battle (Figure 8c). No other deposits have been worked deeper than 100m below NGS datum in the region, but the Weald is an historic area of iron exploitation (also shown on Figure 8c) and iron ores were extracted from shallow workings until the late 18th century.

Depleted hydrocarbon fields have been considered for underground gas storage within the region, but so far none have progressed to the planning application stage.

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

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. Although south-east England shows low levels of seismicity onshore, there have been at least 3 earthquakes with magnitudes of 5Mw or greater in the Strait of Dover in last 1,000 years. These earthquakes occurred in 1382, 1449 and 1580 and were all felt over a wide area, including London and northern France with records of damage. More recently, a magnitude 4Mw earthquake occurred near Folkestone on 28 April 2007. This resulted in emergency measures being taken by the local authority, power outages, transport disruption and superficial damage to buildings due to the combination of a shallow focus and the topography at the site.

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.

It is widely accepted that the Wealden District did not experience continental or lowland-scale glaciations during the last two and half million years. Based upon this, it is also considered unlikely that the region will experience glaciation over the next million years. However, 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 parts of the region are 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 Wealden District region as defined for the purpose of National Geological Screening.

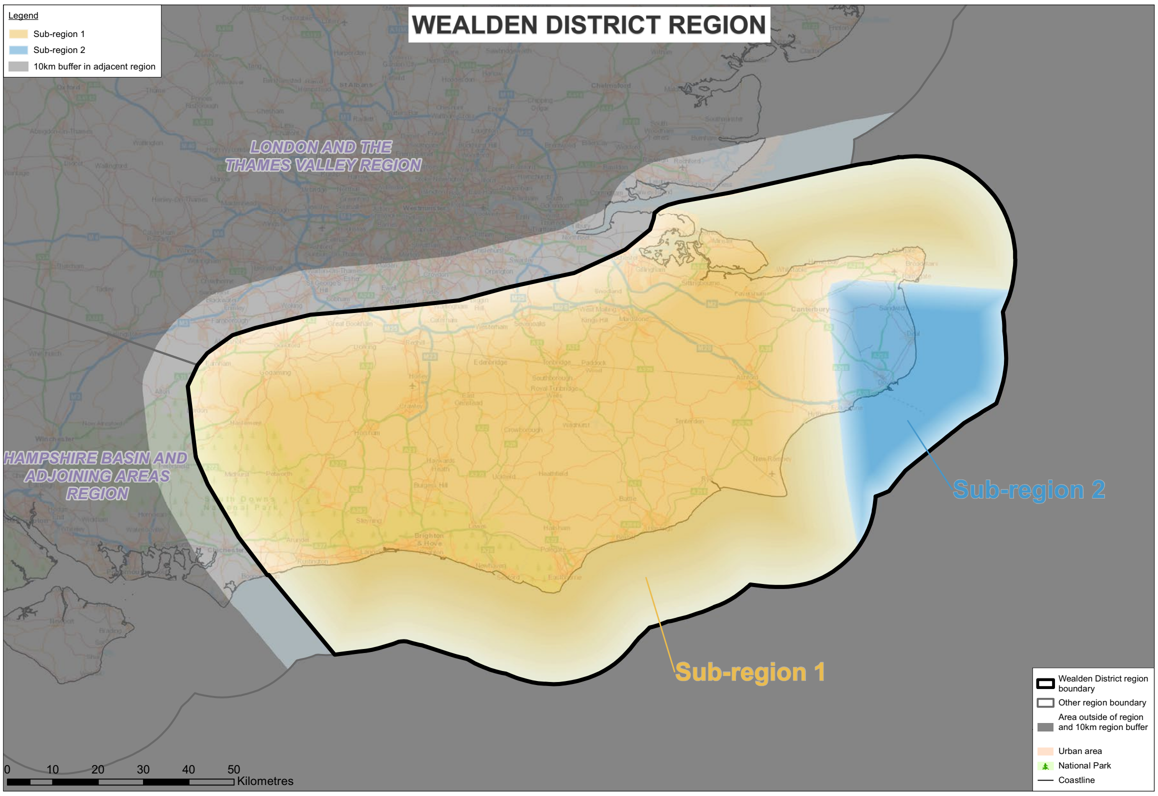
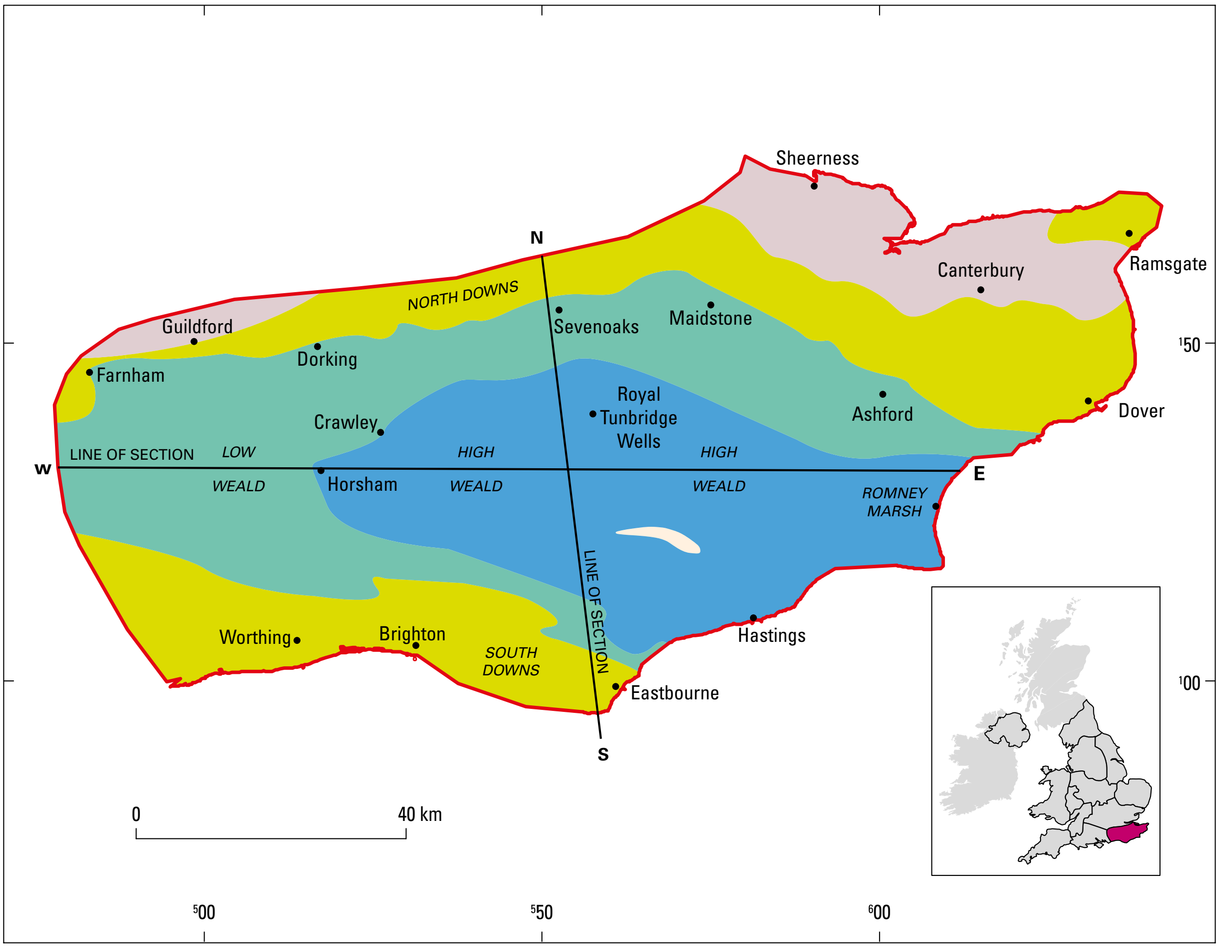


Figure 2 Table illustrating the sequence of major rock units present in the Wealden District region and their possible significance for the siting of a GDF[4] .

	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)	London Clay Lambeth Group Thanet Sand	Not applicable as not in depth range of interest	Not applicable as not in depth range of interest		
Younger Sedimentary Rocks	Cretaceous (66.0 – 145.0)	Chalk Group	chalk			
Younger Sedimentary Rocks	Cretaceous (66.0 – 145.0)	Upper Greensand Formation	sandstone and siltstone			
Younger Sedimentary Rocks	Cretaceous (66.0 – 145.0)	Gault Formation	mudstone and siltstone	✓		
Younger Sedimentary Rocks	Cretaceous (66.0 – 145.0)	Lower Greensand Group	sandstone and mudstone			
Younger Sedimentary Rocks	Cretaceous (66.0 – 145.0)	Wealden Group	mudstone, siltstone and sandstone	✓		
Younger Sedimentary Rocks	Cretaceous (66.0 – 145.0)	Purbeck Group	limestone and mudstone			
Younger Sedimentary Rocks	Jurassic (145.0 – 201.3)	Portland Group	sandstone, siltstone and mudstone (including Portland Stone aquifer)	✓		
Younger Sedimentary Rocks	Jurassic (145.0 – 201.3)	Kimmeridge Clay Formation	mudstone with siltstone, sandstone, and limestone	✓		
Younger Sedimentary Rocks	Jurassic (145.0 – 201.3)	Corallian Group	limestone, sandstone, siltstone and mudstone	✓		
Younger Sedimentary Rocks	Jurassic (145.0 – 201.3)	Oxford Clay and Kellaways Formations	mudstone and siltstone	✓		
Younger Sedimentary Rocks	Jurassic (145.0 – 201.3)	Great Oolite Group	sandstone, limestone and mudstone			
Younger Sedimentary Rocks	Jurassic (145.0 – 201.3)	Inferior Oolite Group	limestone, sandstone, siltstone and mudstone			
Younger Sedimentary Rocks	Jurassic (145.0 – 201.3)	Lias Group	mudstone, siltstone, limestone and sandstone	✓		
Younger Sedimentary Rocks	Triassic (201.3 – 251.9)	Mercia Mudstone Group	mudstone, siltstone and sandstone	✓		
Older Sedimentary Rocks	Carboniferous (298.9 – 358.9)	Warwickshire Group	sandstone and mudstone with coal seams	✓		
Older Sedimentary Rocks	Carboniferous (298.9 – 358.9)	Pennine and South Wales Coal Measures Groups	mudstone, siltstone, sandstone and coal			
Older Sedimentary Rocks	Carboniferous (298.9 – 358.9)	Carboniferous Limestone Supergroup	limestone and mudstone			
Older Sedimentary Rocks	Devonian (358.9 – 419.2)	Devonian rocks	mudstone, siltstone and sandstone (slaty in the south of the region)		✓	
Basement	Silurian (419.2 – 443.8)	Undifferentiated	mudstone, siltstone and sandstone		✓	
Basement	Ordovician and Cambrian (443.8 – 541.0)	Undifferentiated	(slaty in the south of the region)			

Figure 3 Generalised geological map showing the distribution of rock units in the Wealden District 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.



[4] 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 4 Schematic cross-section through the Wealden District region from north to south. The alignment of the 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.

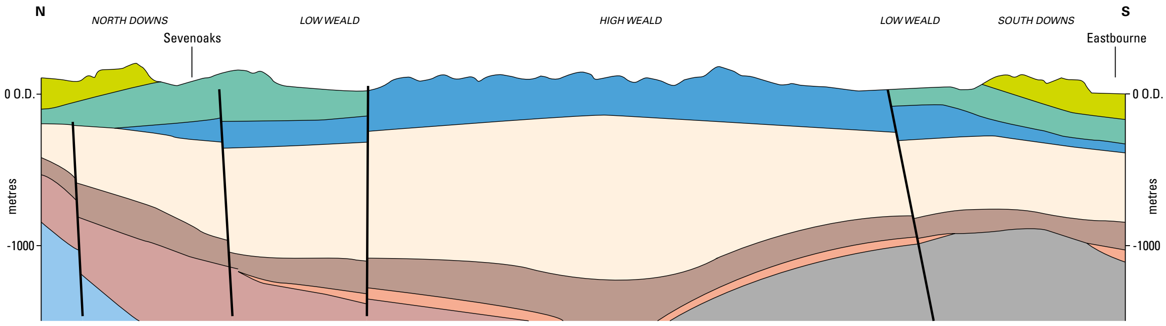


Figure 5 Schematic cross-section through the Wealden District region from west to east. The alignment of the section is shown in Figure 3. Note that the vertical scale is greatly exaggerated and actual dips of rock layers are much gentler than they appear here. See Figure 2 for the key to the rock types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

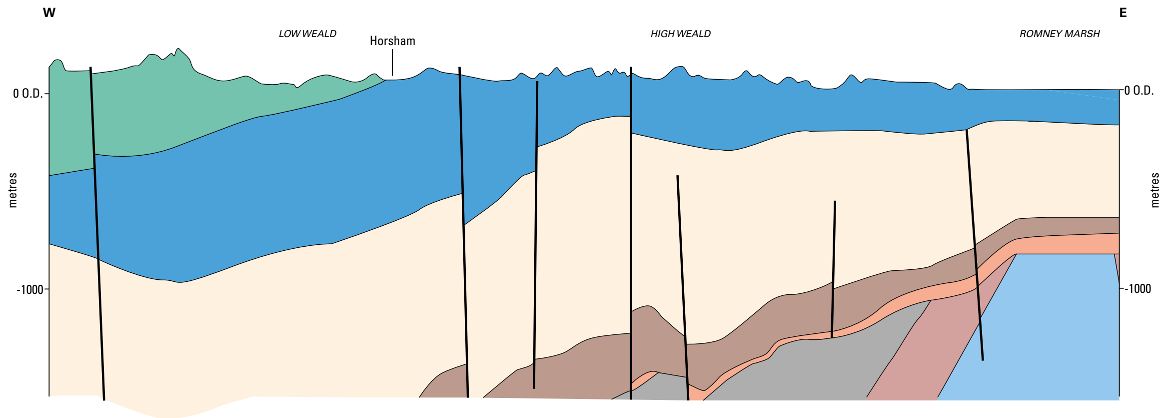


Figure 6a The areas of the Wealden District region where any of the 3 Rock Types of Interest are present between 200 and 1,000m below NGS datum

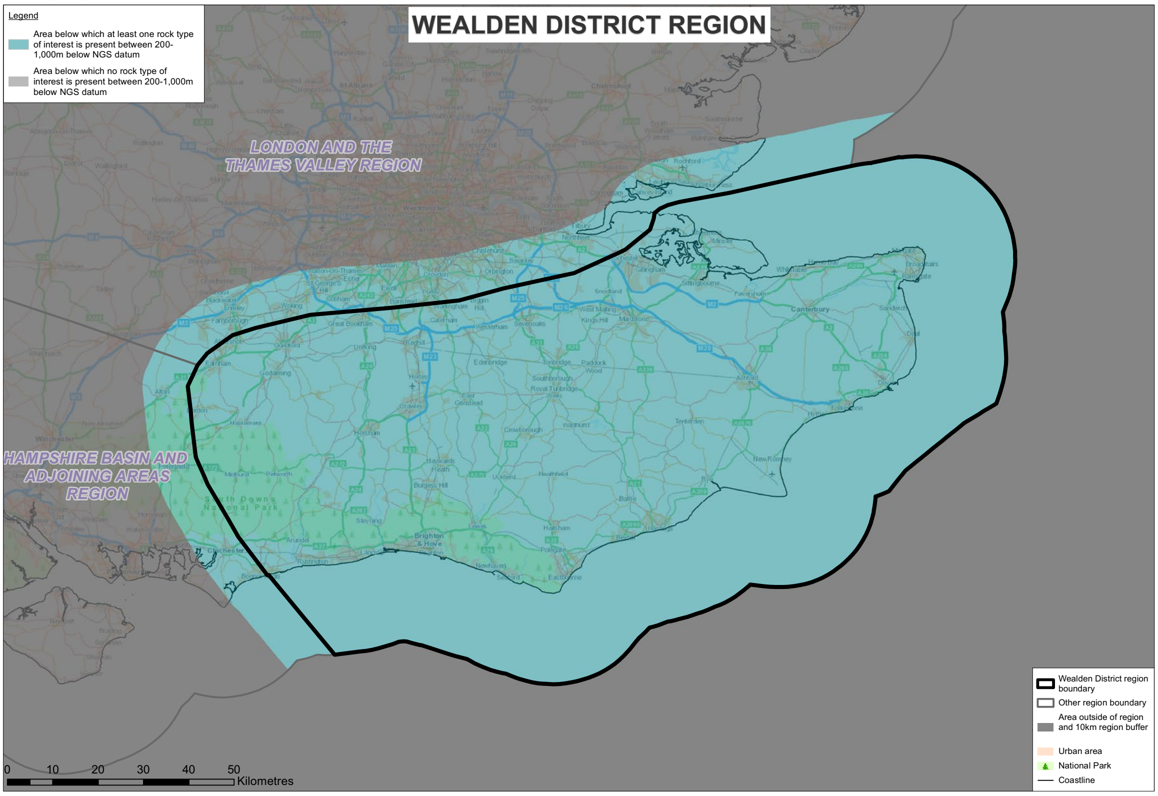


Figure 6b The areas of the East Anglia region where Lower Strength Sedimentary Rock Types of Interest are present between 200 and 1,000m below NGS datum.

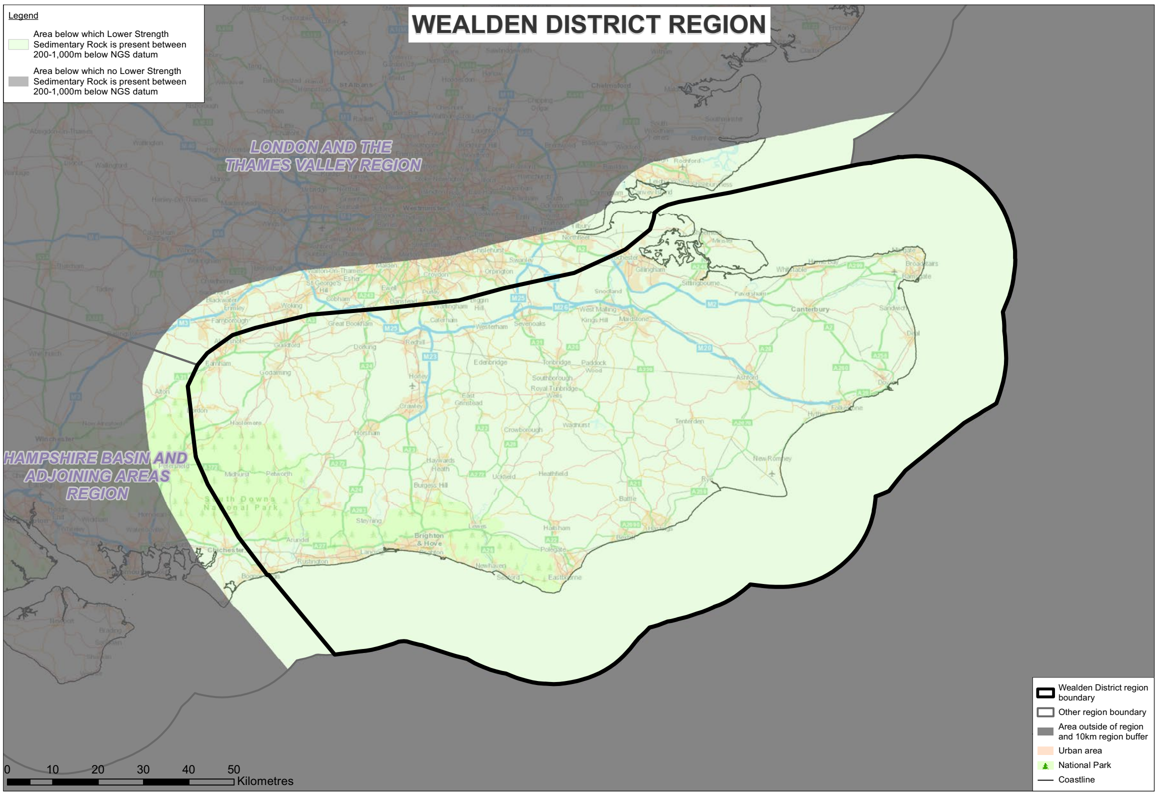


Figure 6c The areas of the Wealden District region where Higher Strength Rock Types of Interest are present between 200 and 1,000 m below NGS datum.

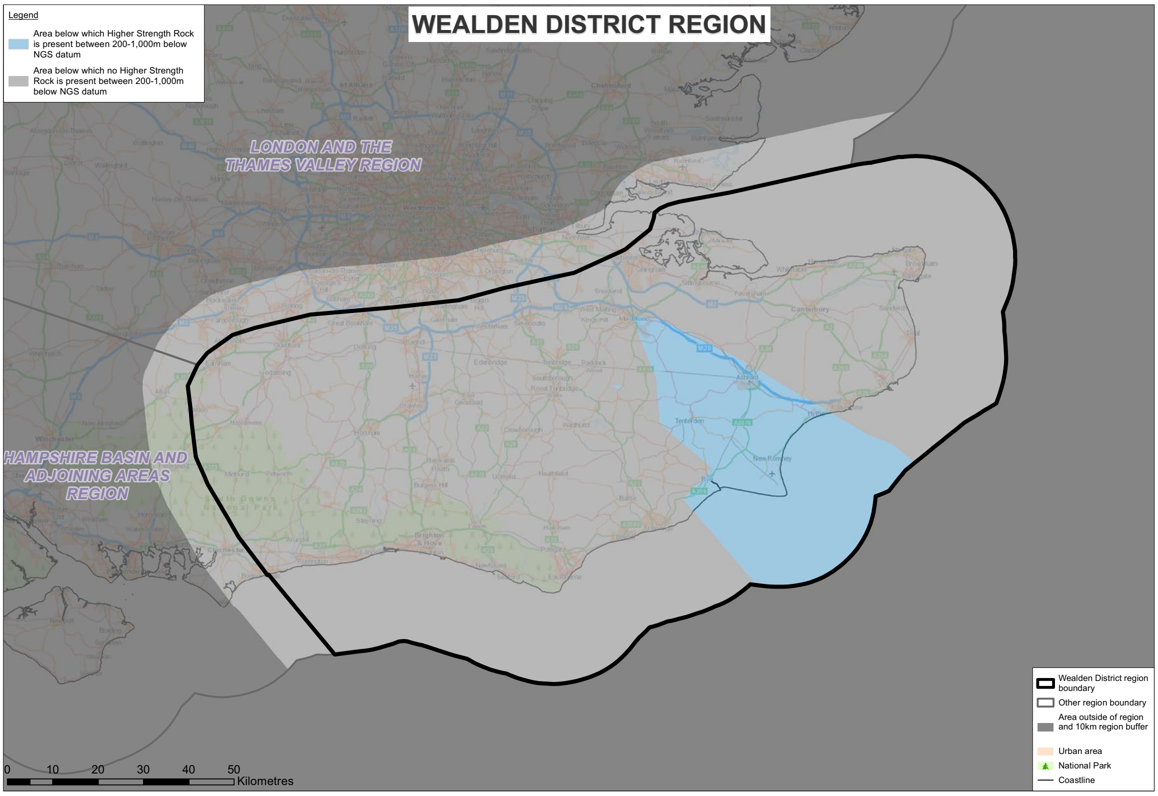


Figure 7 Location of major faults and folds in the Wealden District region.

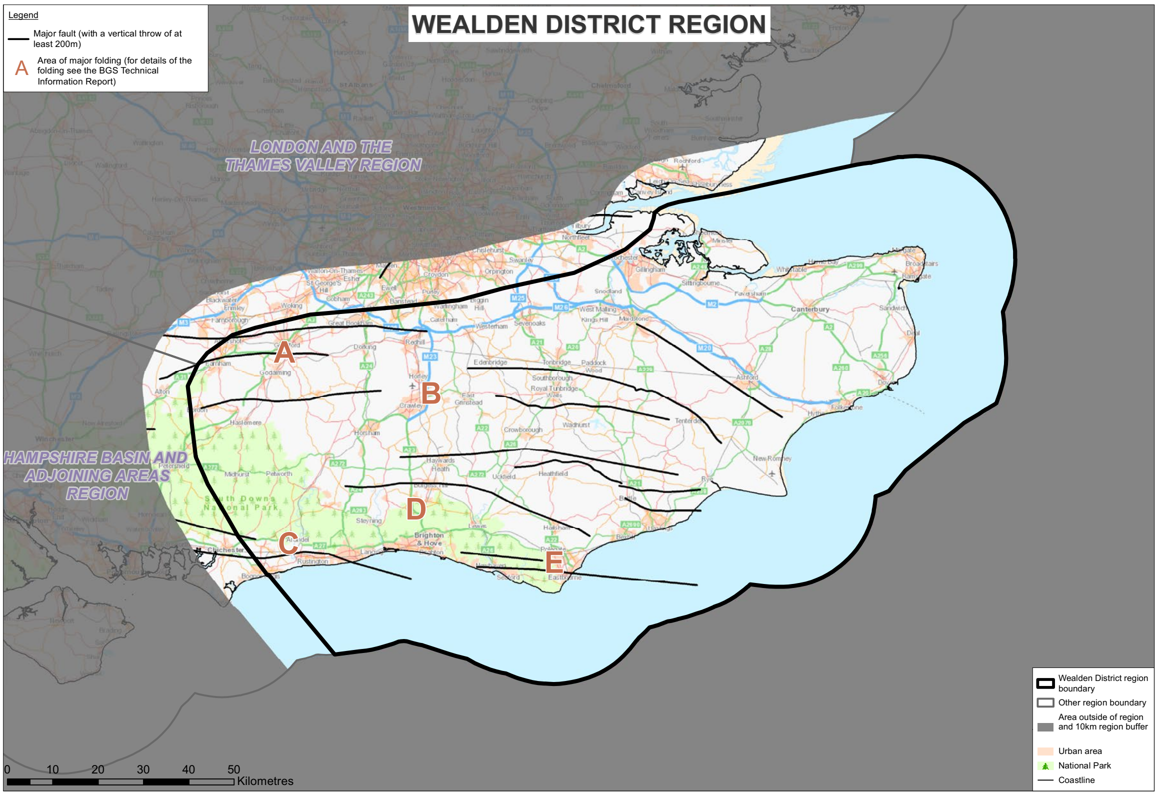


Figure 8a Areas of the Wealden District region with coal mines present below 100m and Coal Authority Licence Areas.

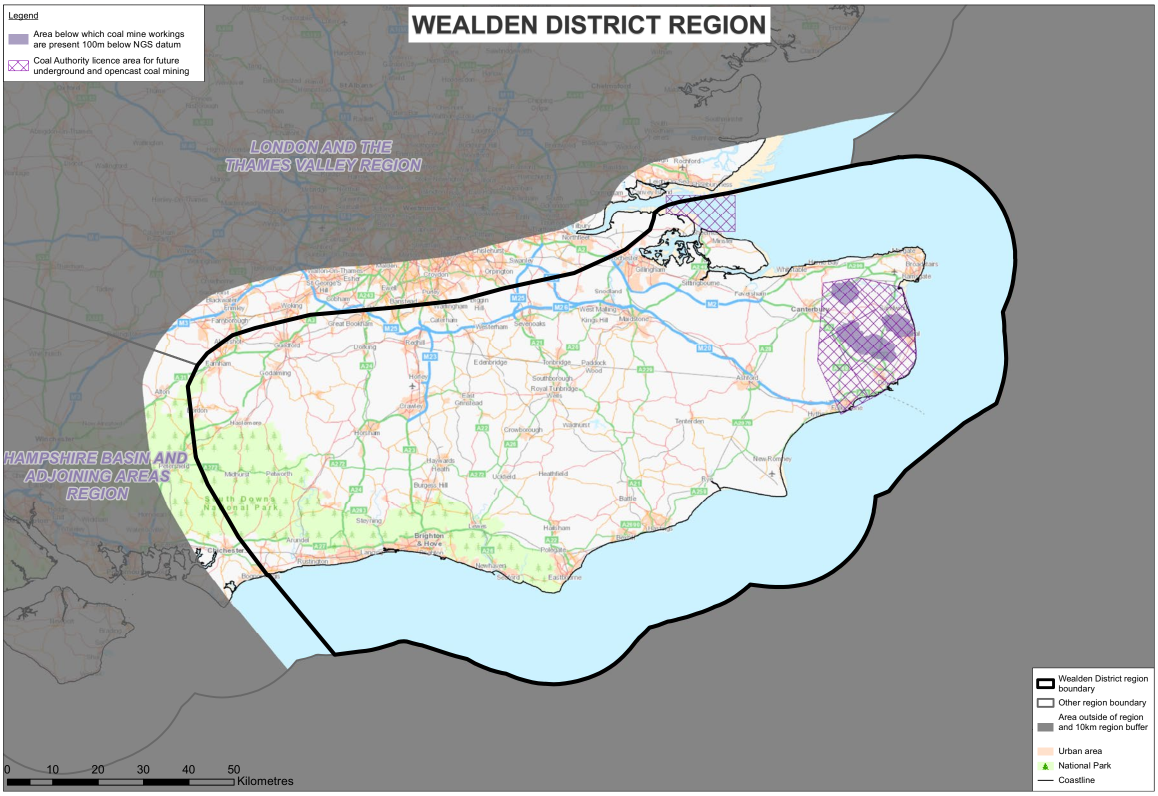


Figure 8b Areas of the Wealden District region with oil and gas fields and Petroleum Exploration and Development Licences.

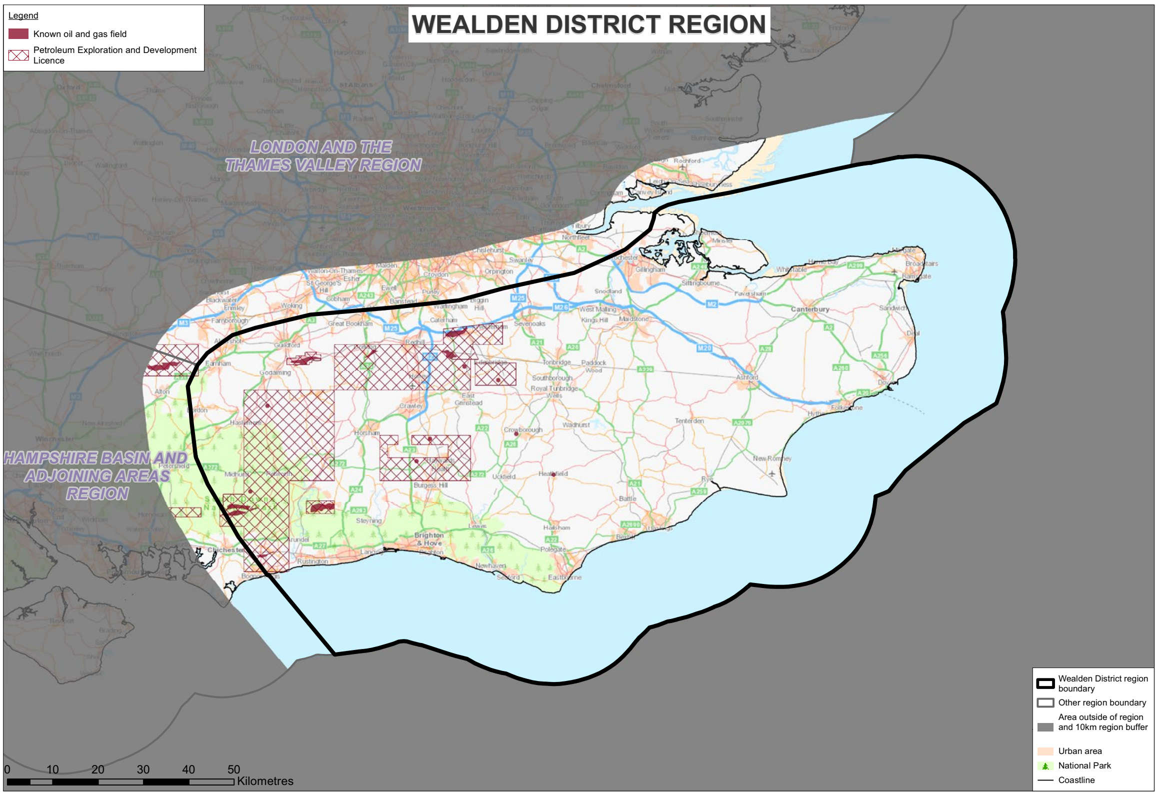


Figure 8c Areas of the Wealden District region with historical iron ore mines less than 100m deep and evaporite mines present below 100m.

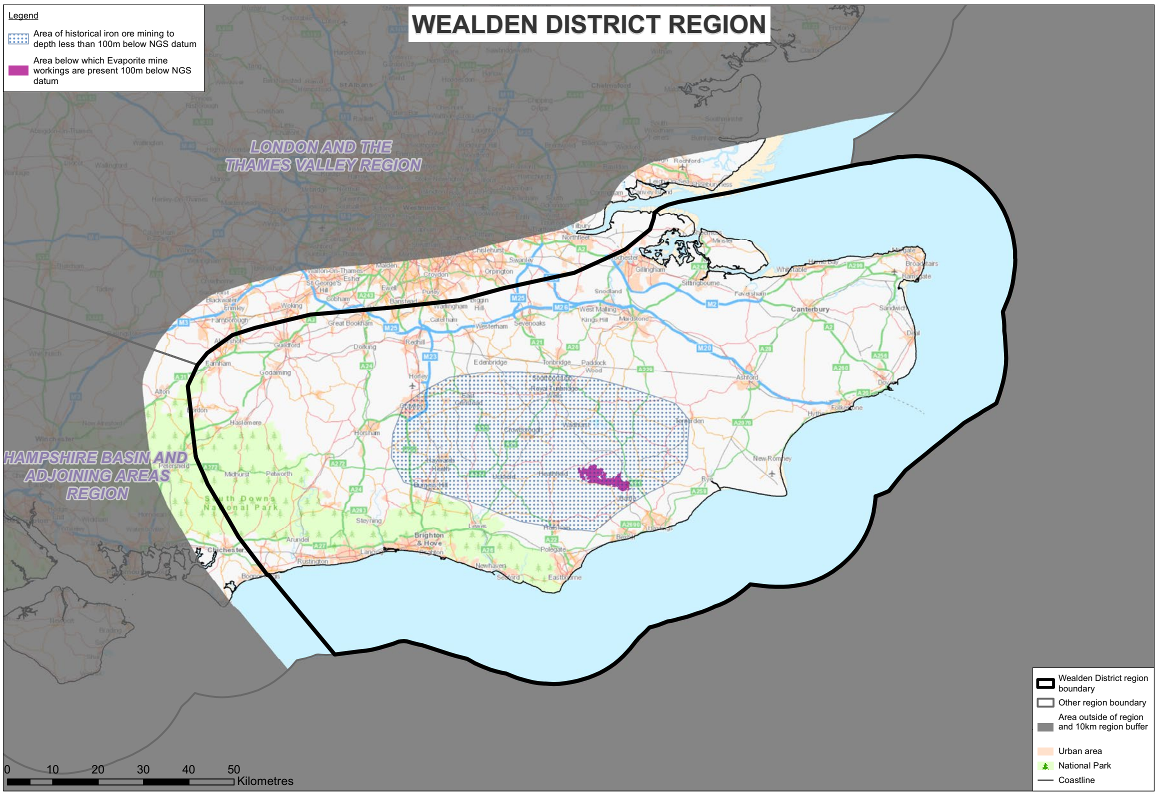
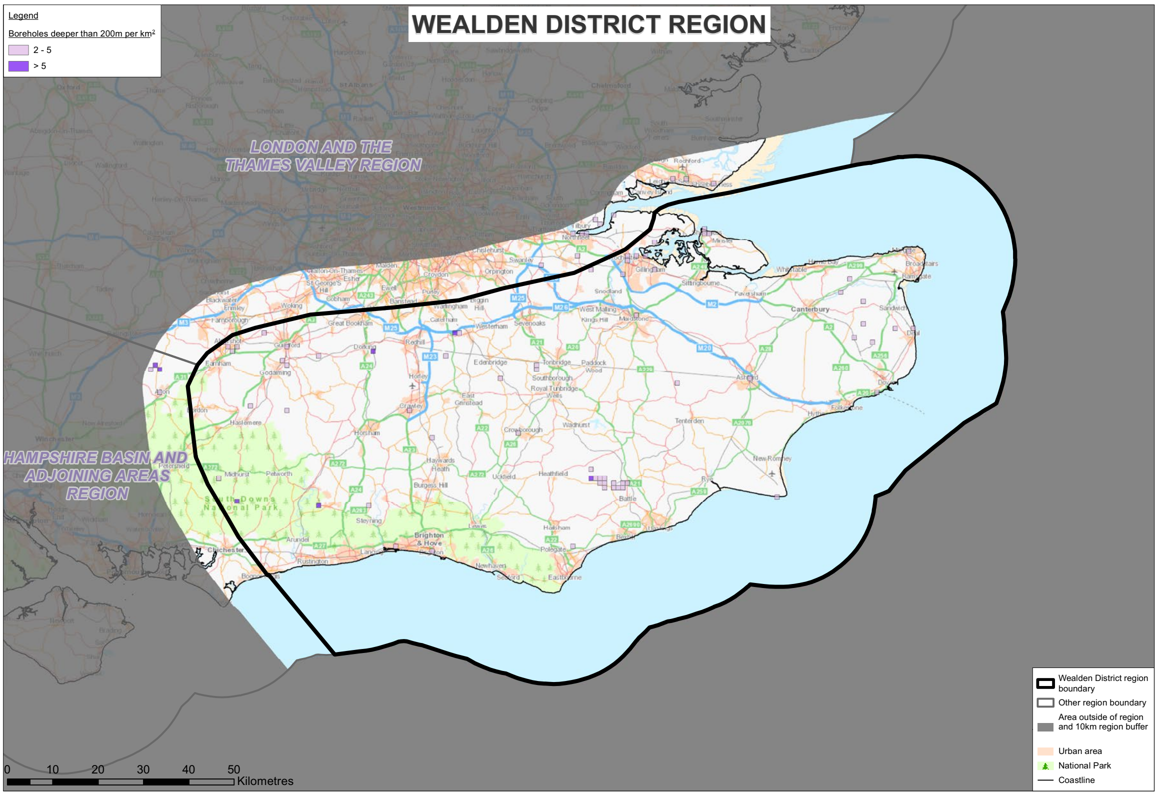


Figure 9 Location of intensely drilled areas in the Wealden District region.



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.

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.

Dolomite
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.

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.

Gas storage facilities
Underground facilities where gas can be pumped and stored under pressure. These can be within man-made caverns in salt deposits or by pumping gas into depleted oil and gas reservoirs. The gas can then be extracted again when demand is high.

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.

Lithology
The physical properties of rock types

Monocline
Step-shaped fold in layered rock strata.

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.

Monocline
Step-shaped fold in layered rock strata.

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

Sediments
Solid fragmented material, such as silt, sand, gravel and other material (including chemical precipitates, like salt), deposited in rivers, lakes, seas and oceans. Generally, the material that accumulates has originated from the weathering of other rocks. This material is often transported by erosion and deposited in layers. Sediments form the building blocks of sedimentary rocks
(see below).

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.

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'.

Shale oil
Oil that is naturally generated and trapped within shales that contain a high amount of organic material . Shale oil can be extracted by a technique known as hyrdaulic fracturing or 'fracking' and used as a fuel in heating or power generation, or refined into petroleum products.

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

Tectonic plates
The outermost 125km 'skin' of the earth made up of rigid rocks that move and grind against each other due to the action of heat circulating deep in the earth's interior

Variscan
An episode of mountain-building during the Carboniferous period that led to deformation of the basement rocks of much of the southern UK.

Weald anticline
Large anticline in SE England that formed at the same time as the Alps, and which has now been deeply eroded. Tilted layers of Chalk around the edge of the Weald make up the North and South Downs.

Radioactive Waste Management

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