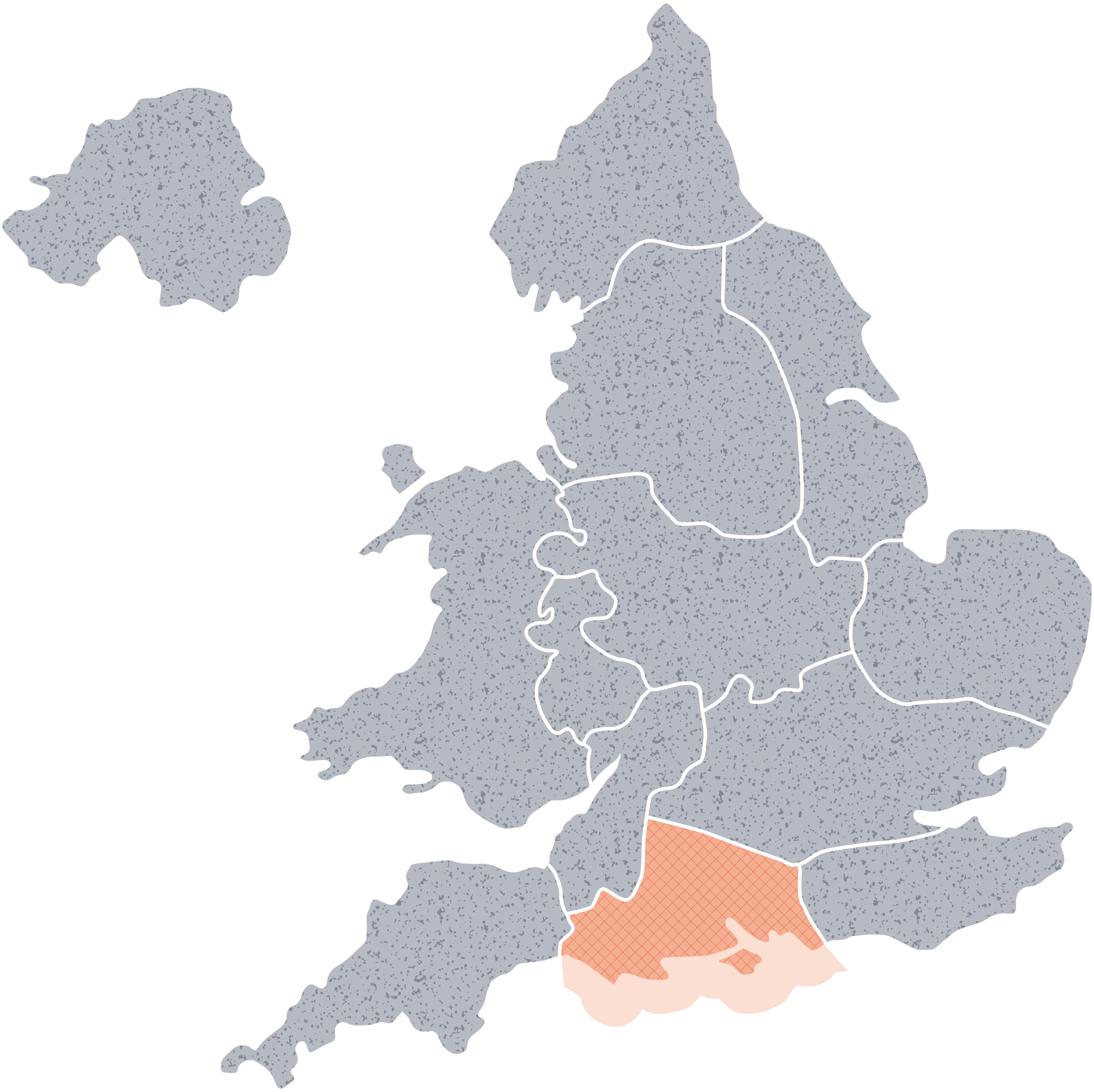
Radioactive Waste Management



Hampshire Basin

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 includes the whole of Dorset, most of Wiltshire and Hampshire, the Isle of Wight and the western part of West Sussex. 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 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.

Hampshire Basin and adjoining areas: 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

The extensive rock exposures in coastal cliffs, which include the 'Jurassic Coast' World Heritage Site, have helped geological mapping of the region. There are more than 250 boreholes drilled to more than 150m depth in search of water, oil, and gas, in various parts of the region. Some of the deepest boreholes, in the west of the region, reach 3km depth. 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. The amount of information available means that the types of rock present in the depth range of interest are reasonably well known. However, the displacement of rock layers across the numerous faults affects the continuity of rock available to host a GDF. 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 2 groups: younger sedimentary rocks and older sedimentary 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 2 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 younger of the 2 main groups of rocks comprises a sequence of sedimentary rocks, including mudstones, limestones and sandstones, deposited since the Permian period (approx. 250 million years ago). The sediments were deposited in a broad depression known as the Wessex Basin. The youngest Cenozoic and Upper Cretaceous rocks (younger than approx. 100 million years old), including the Gault Clay Formation and Chalk Group, were deposited onto rocks which become progressively older towards the west.

There are several rock units in this younger sedimentary rock sequence that contain thick, extensive mudstone layers and are likely to behave as LSSR. Most of these rocks can be seen in the sea cliffs along the coasts of east Devon, Dorset, Hampshire and the Isle of Wight and all are well known from drilling across a large part of the region. They include the Wealden Group (up to 1,000m thick at Swanage), Kimmeridge Clay Formation (up to 500m thick on the south coast), Oxford Clay Formation (up to 185m in south Dorset) and Mercia Mudstone Group (up to 900m thick in south Dorset). Within the depth range of interest the younger Wealden Group occurs in the east of the region and on the Isle of Wight. The Upper Jurassic mudstones (Kimmeridge and Oxford Clay Formations) occupy a north-south band in the centre of the region and the older Mercia Mudstone Group occurs in the west. The Gault Clay Formation is present in the depth range of interest under most of the region except for the far west and north-west (see Figures 4 and 5). In addition to these thicker mudstones there are several other mudstone layers in the younger sedimentary rock sequence, shown in Figure 2.

The Dorset Halite Formation comprises a significant thickness of rock salt (halite) within the depth range of interest in south-west Dorset and may be a potential Evaporite host rock.

Older sedimentary rocks

Sedimentary rocks of Carboniferous and Devonian age (approx. 300 to 420 million years old) occur below most of the region (rocks shown in purple in Figures 4 and 5) but only occur within the depth range of interest around Melksham and Yeovil (see Figure 6c). These are referred to here as older sedimentary rocks and include limestones, sandstones and mudstones. They have been buried sufficiently deeply such that they are now more highly compacted compared to the younger sedimentary rocks above. Also they are located in a zone of rock deformation extending from south-west England and south Pembrokeshire east across the south of England and some of the mudstones have been folded and metamorphosed to form schist-like rocks.

There is insufficient information available at present to know whether these older sedimentary rocks or any basement rocks which may be present would be suitable to host a GDF.

Rock structure

The region is characterised by discrete zones of folding and faulting aligned in an east-west direction, with wider less deformed areas in between. The main structural zones are: the Pewsey-Basingstoke, Mere-Wardour-Portsdown, Cranborne-Fordingbridge, and Abbotsbury-Ridgeway-Purbeck-Isle of Wight structures (see Figure 7). They are related to fault structures which formed in the underlying basement rocks during the collision of tectonic plates 280 to 380 million years ago and were reactivated by compressive forces approximately 20 million years ago. These fault zones were active during the deposition of the Cretaceous and Jurassic sediments and therefore influence the local thickness variations of many of the LSSR layers. The more recent episodes of reactivation have extended the fault tips into the younger overlying rocks meaning they could provide pathways for groundwater movement to the near-surface.

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.

The most significant folding in the region is associated with reversal of movement on the main fault zones during the formation of the Alps (which began approx. 65 million years ago). This has caused layers to dip steeply in the areas shown on Figure 7, with near-vertical beds in the Sandown, Needles and Purbeck monoclines.

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 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. Beneath the mudstones, the Sherwood Sandstone Group and the Carboniferous Limestone aquifer are present at depth in this region. In some other regions these rocks occur at shallow depths and are principal aquifers but in this region they are deeper than 400m and their groundwater has not been sampled. It is likely that they contain 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 not used for drinking water anywhere in UK[1].

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

Resources

There are several oil and gas fields and Petroleum Exploration and Development Licences[2] for onshore oil fields in the region (see Figure 8). These fields include formerly the largest onshore oilfield in Europe at Wytch Farm near Wareham and others near Andover, Winchester, Alton, Horndean, Kimmeridge (just west of Swanage) and Moreton (west of Wareham). One of the licences extends slightly into the London and Thames Valley region between Basingstoke and Farnham.

Parts of the region contain mudstones or shales that have been identified as having potential for shale oil and/or shale gas. These include an area immediately north of the Wytch Farm field and part of the Wealden District area of potential for shale oil that extends into the eastern part of the region between Farnham and Petersfield.

Rock salt underlies at least 1,200km2 of the south-west of this region between Bridport, just north of Abbotsbury, and Poole. However, the Dorset Halite Member has never been exploited and it is highly unlikely to be utilised for salt production because of its commercially uneconomic depth. However, thick, relatively pure rock salt (halite) units could be considered for gas storage or similar uses.

The region was evaluated by the Department of Energy for its geothermal potential in the 1980s, testing the Sherwood Sandstone Group. In 1986, 2 boreholes were drilled at Marchwood, just south of Totton, and Southampton and a geothermal power scheme currently provides heating to the Southampton District Energy Scheme in the city centre. Similar potential may apply to other parts of the Hampshire Basin to a greater or lesser extent.

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

[1] Water Framework Directive UK TAG. Defining and reporting on groundwater bodies, 2012.
[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. Earthquake activity in the Hampshire Basin is lower than in many other parts of Britain. There is only 1 record of an earthquake with a magnitude of 4.0Mw or greater: the magnitude 4.4Mw Chichester earthquake of 1963. The epicentre was between Portsmouth and Chichester and it was felt across Sussex and Hampshire. Earthquakes with magnitudes of 4.2 and 4Mw occurred to the south of the region in the English Channel in 1734 and 1750, respectively. The 1734 earthquake was felt on both sides of the English Channel.

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 Hampshire Basin did not experience continental or lowland-scale glaciations during the last 2.5 million years and it is unlikely that the region will experience glaciation over the next million years. Nonetheless, 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 south 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 Hampshire Basin and adjoining areas region as defined for the purpose of National Geological Screening.

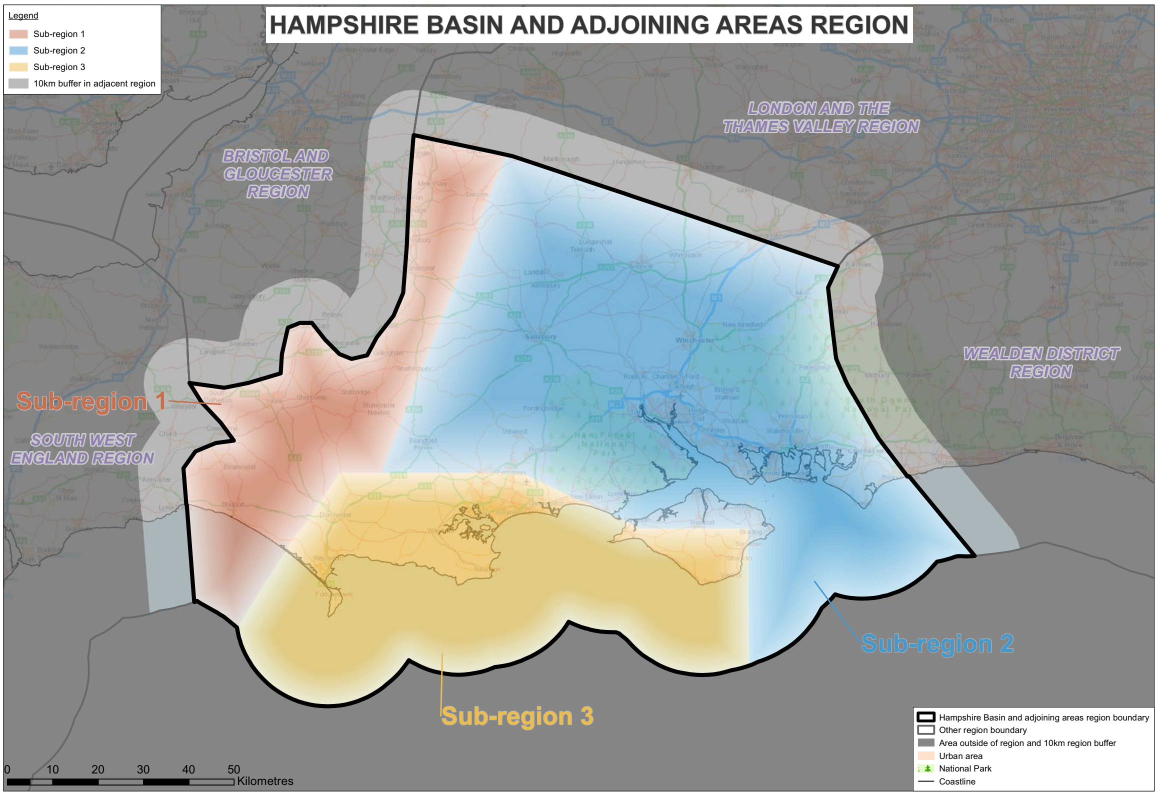


Figure 2 Table illustrating the sequence of the major rock units present in the Hampshire Basin and adjoining areas region and their possible significance for the siting of a GDF.

	Geological Period (age in millions of years)	**Geological Unit**	**Dominant Lithology**	**Rock types of interest**		
				LSSR	HSR	Evaporite
Younger Sedimentary Rocks	Palaeogene (23.0 – 66.0)	Solent Group	clay silt and sand	✓		
		Barton and Bracklesham Groups	sand, silt and clay	✓		
		Thames Group	clay, silt, sand and gravel	✓		
		Lambeth Group	clay, silt, sand and gravel	✓		
	Cretaceous (66.0 – 145.0)	Chalk Group	chalk			
		Upper Greensand Formation	sandstone			
		Gault Formation	mudstone	✓		
		Lower Greensand Group	sandstone and mudstone			
		Wealden Group	mudstone, siltstone, sandstone and limestone	✓		
		Purbeck Group	interbedded limestone and mudstone			
	Jurassic (145.0 – 201.3)	Portland Group	Limestone, sandstone and mudstone			
		Ampthill and Kimmeridge Clay Formations	mudstone with siltstone, sandstone and limestone	✓		
		Corallian Group and Oxford Clay/ Kellaways Formation	limestone, sandstone, siltstone and mudstone	✓		
		Great Oolite Group	sandstone, limestone and mudstones			
		Inferior Oolite Group	limestone, sandstone, siltstone and mudstone			
		Lias Group	sandstone (Bridport Sand Formation only)			
			mudstone, siltstone, and limestone	✓		
	Triassic (201.3 – 251.9)	Penarth Group	Limestone and mudstone			
		Mercia Mudstone Group	mudstone, siltstone and sandstone	✓		
			rock salt (Dorset Halite Formation)			✓
		Sherwood Sandstone Group	sandstone, siltstone and mudstone			
	Permian (251.9 – 298.9)	Aylesbeare Mudstone Group	mudstone, sandstone and conglomerate	✓		

Figure 2 Cont'd Table illustrating the sequence of the major rock units present in the Hampshire Basin and adjoining areas 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
Older Sedimentary Rocks	Carboniferous (298.9 – 358.9)	Pennine and South Wales Coal Measures Groups	mudstone, siltstone, sandstone			
		Carboniferous Limestone Supergroup	limestone, sandstone and mudstone			
	Devonian (358.9 – 419.2)	Middle and Upper Devonian rocks	mudstone, sandstone, phyllite, slate and limestone		✓	
Basement Rocks	Lower Palaeozoic (older than 419.2)	Silurian rocks	mudstone, siltstone and sandstone		✓	
		Cambrian and Ordovician rocks	mudstone, siltstone and sandstone			

Figure 3 Generalised geological map showing the distribution of rock units in the Hampshire Basin and adjoining areas 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.

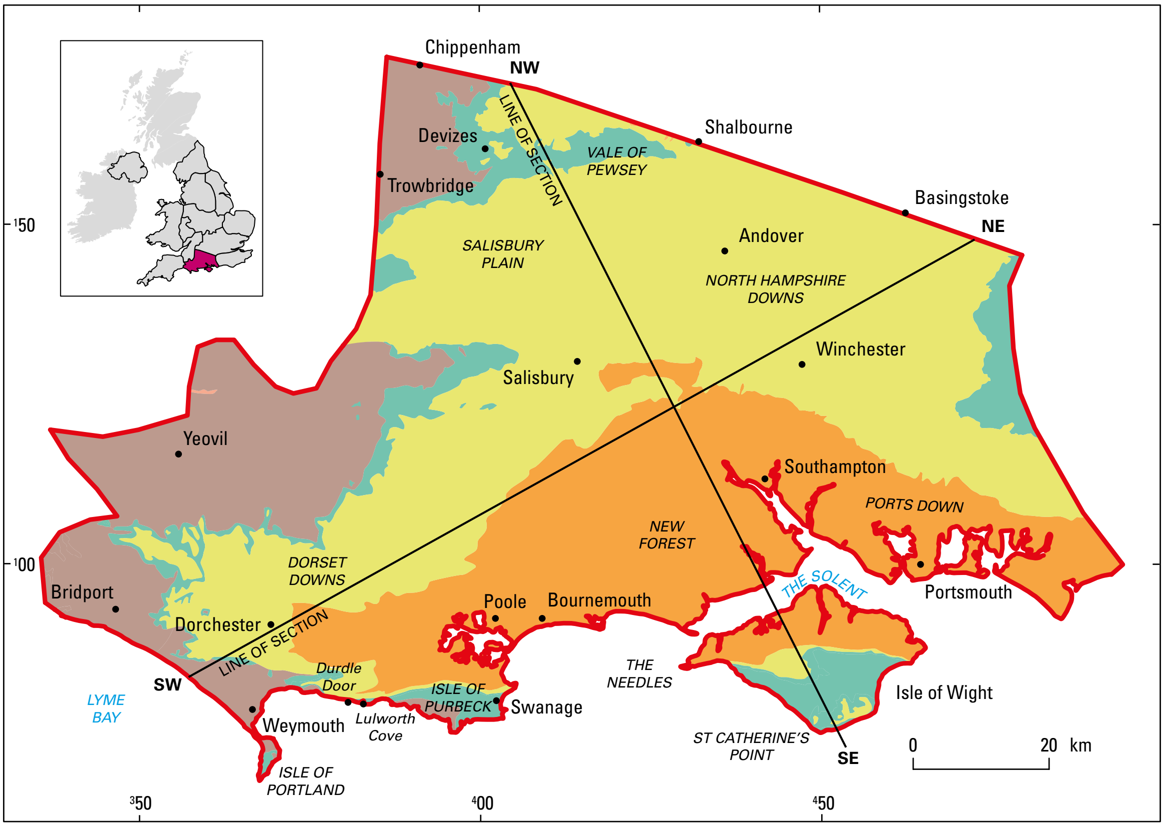


Figure 4 Schematic cross-section of the underlying geology from the Vale of Pewsey in NW Wiltshire towards the Isle of Wight. The line of section can be seen on Figure 3. Note that the vertical scale is greatly exaggerated and actual dips of rock layers are much gentler than they appear here. See Figure 2 for the key to the rock types shown.

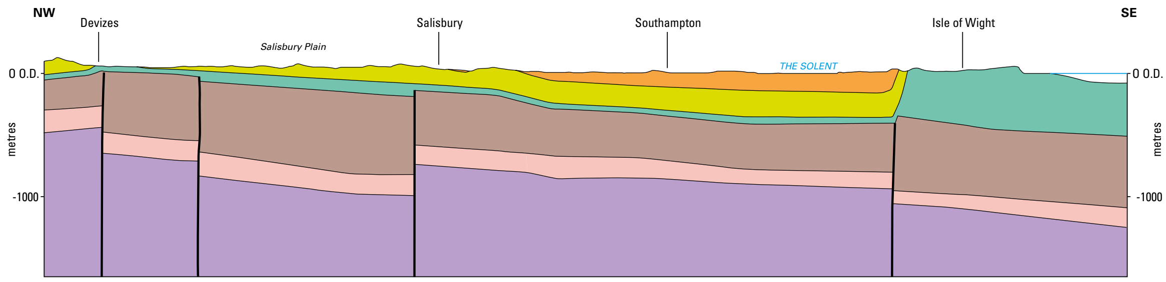


Figure 5 Schematic cross-section of the underlying geology from Lyme Bay in Dorset through the New Forest and on to NE Hampshire. The line of section can be seen on Figure 3. Note that the vertical scale is greatly exaggerated and actual dips of rock layers are much gentler than they appear here. See Figure 2 for the key to the rock types shown.

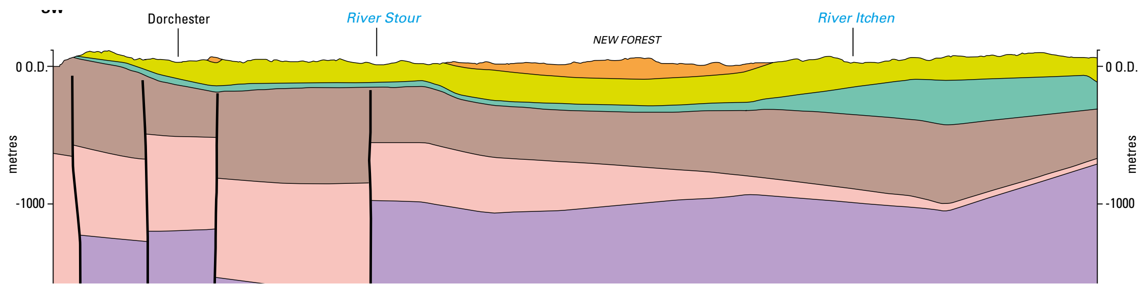


Figure 6a The areas of the Hampshire Basin and adjoining areas region where any of the 3 Rock Types of Interest are present between 200 and 1,000m below NGS datum.

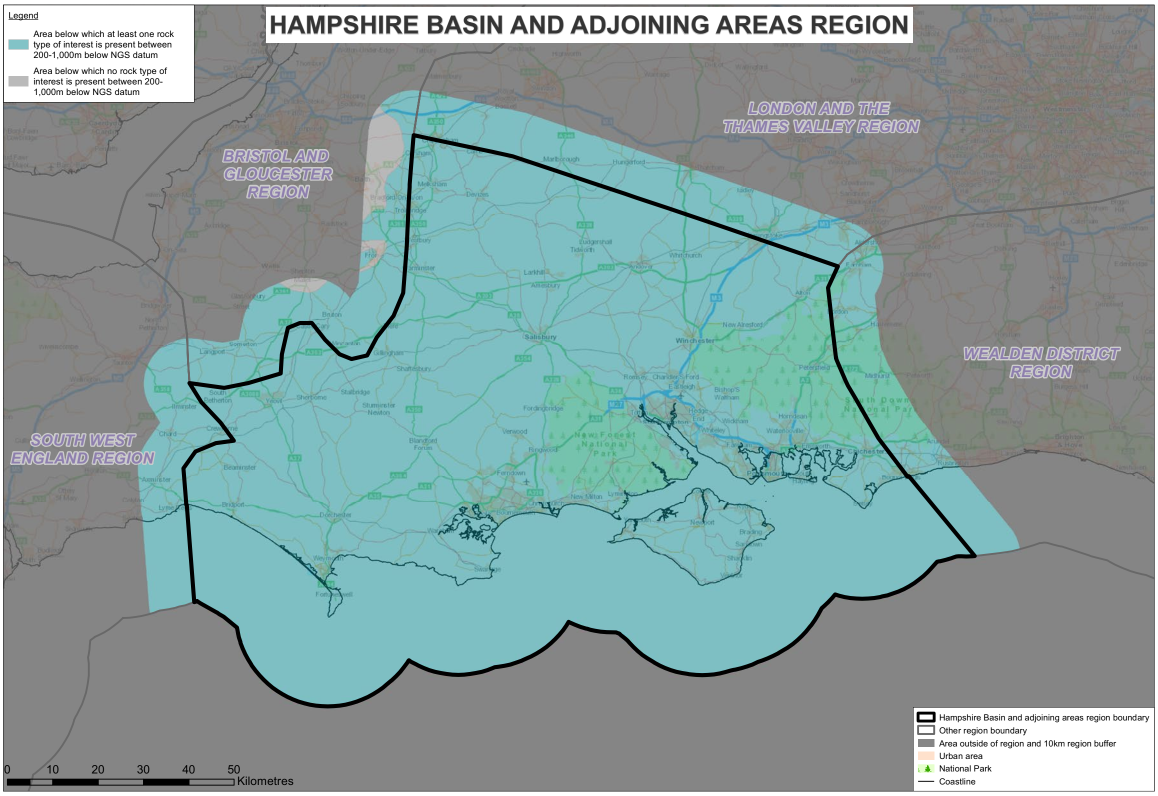


Figure 6b The areas of the Hampshire Basin and adjoining areas region where Lower Strength Sedimentary Rock Types of Interest are present between 200 and 1,000m below NGS datum

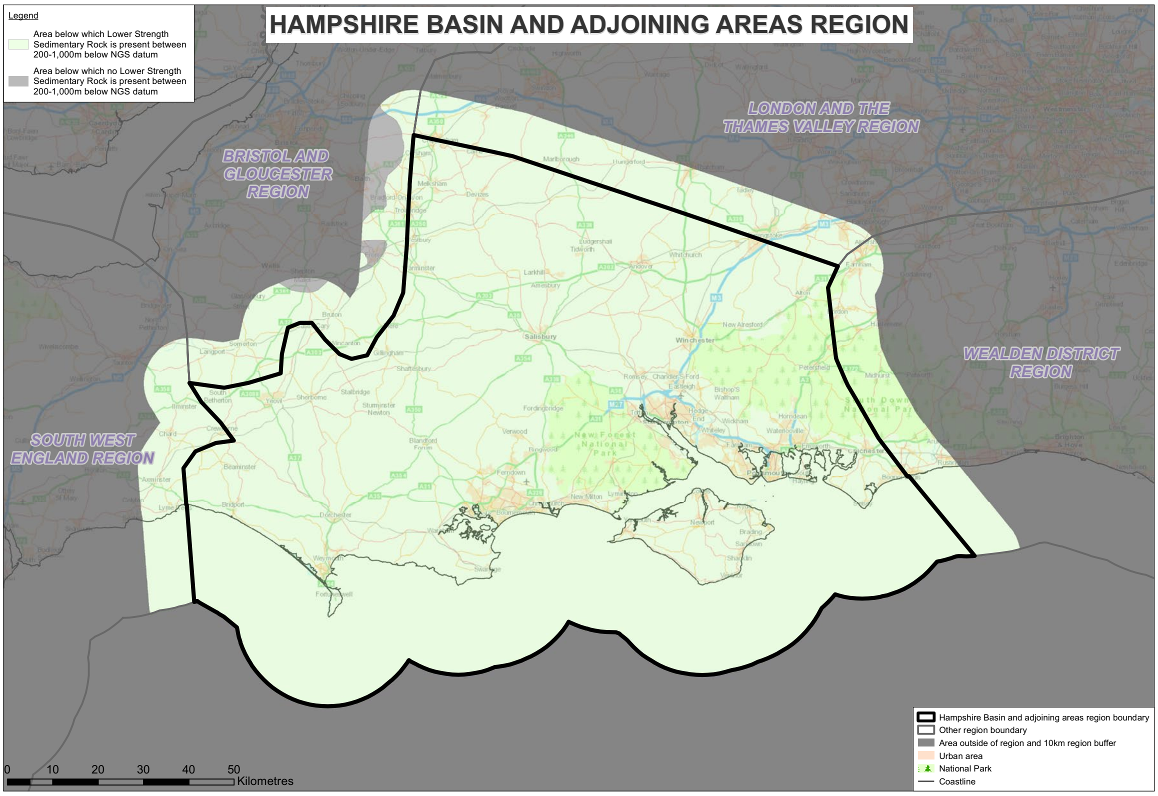


Figure 6c The areas of the Hampshire Basin and adjoining areas region where Higher Strength Rock Types of Interest are present between 200 and 1,000m below NGS datum.

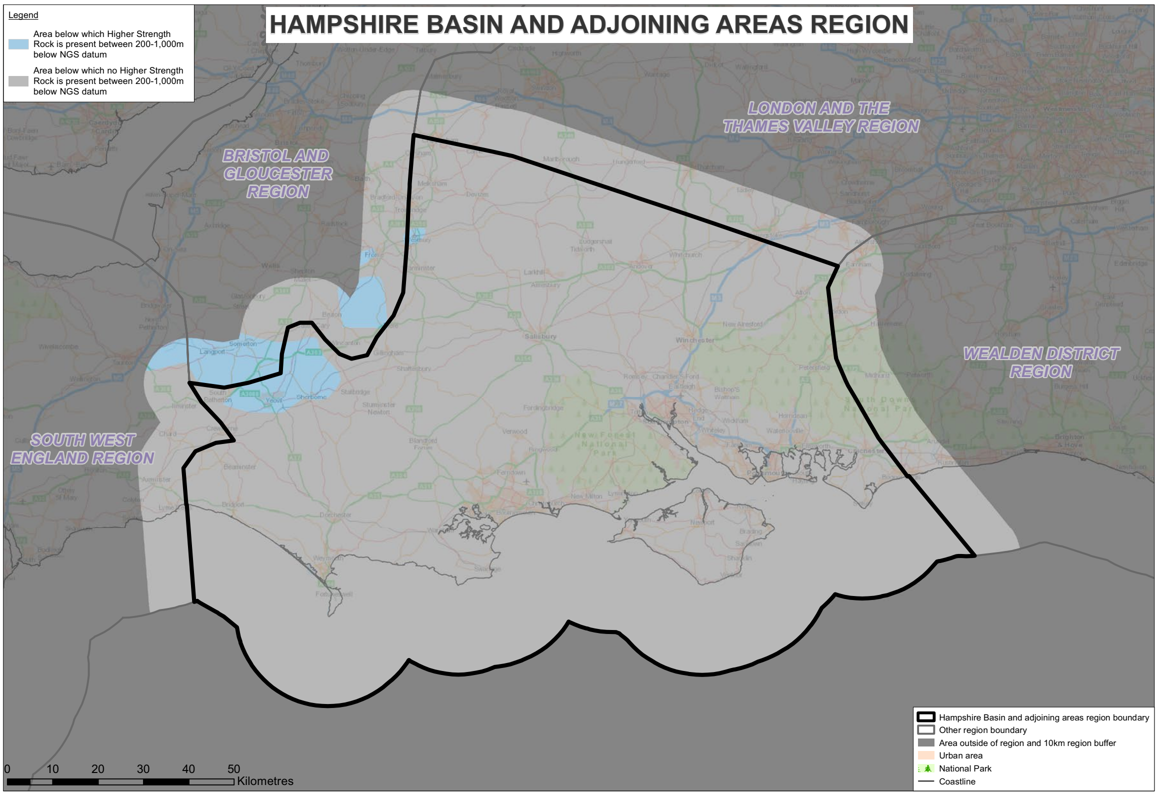


Figure 6d The areas of the Hampshire Basin and adjoining areas region where Evaporite Rock Types of Interest are present between 200 and 1,000m below NGS datum.

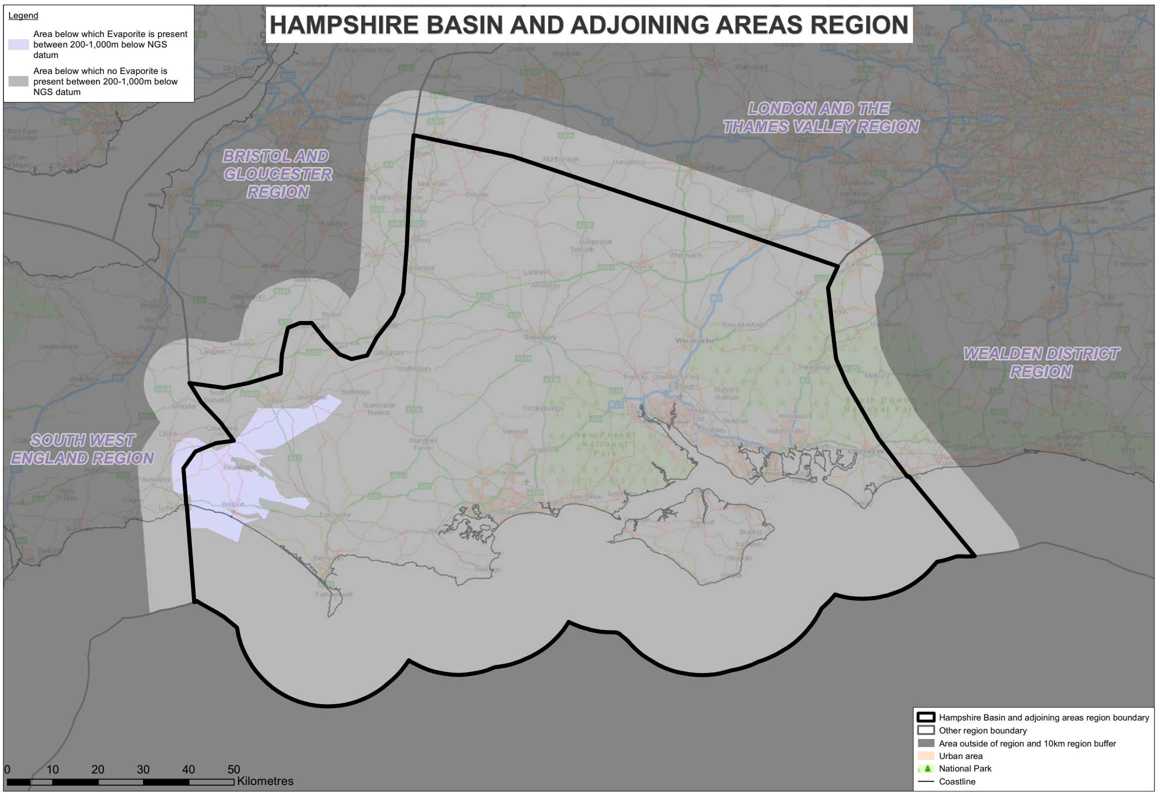


Figure 7 Location of major faults and folds in the Hampshire Basin and adjoining areas region.

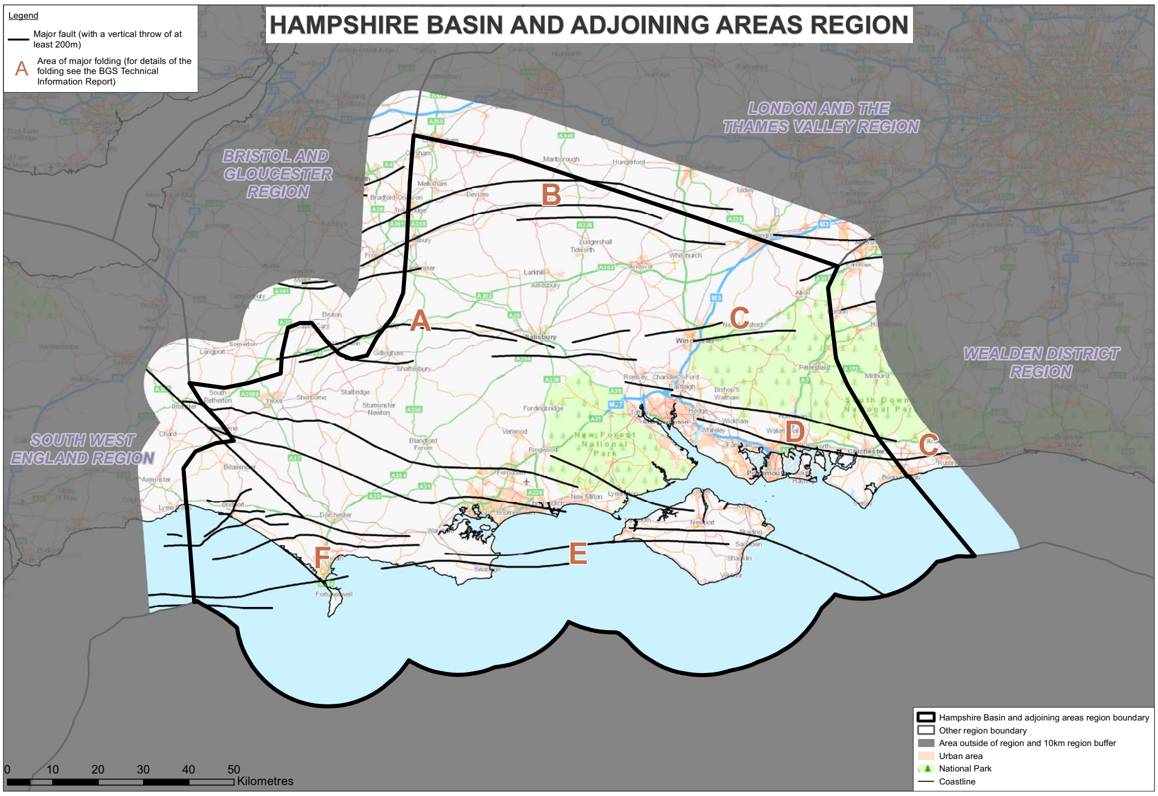


Figure 8 Areas of the Hampshire Basin and adjoining areas region with oil and gas fields and Petroleum Exploration and Development Licences

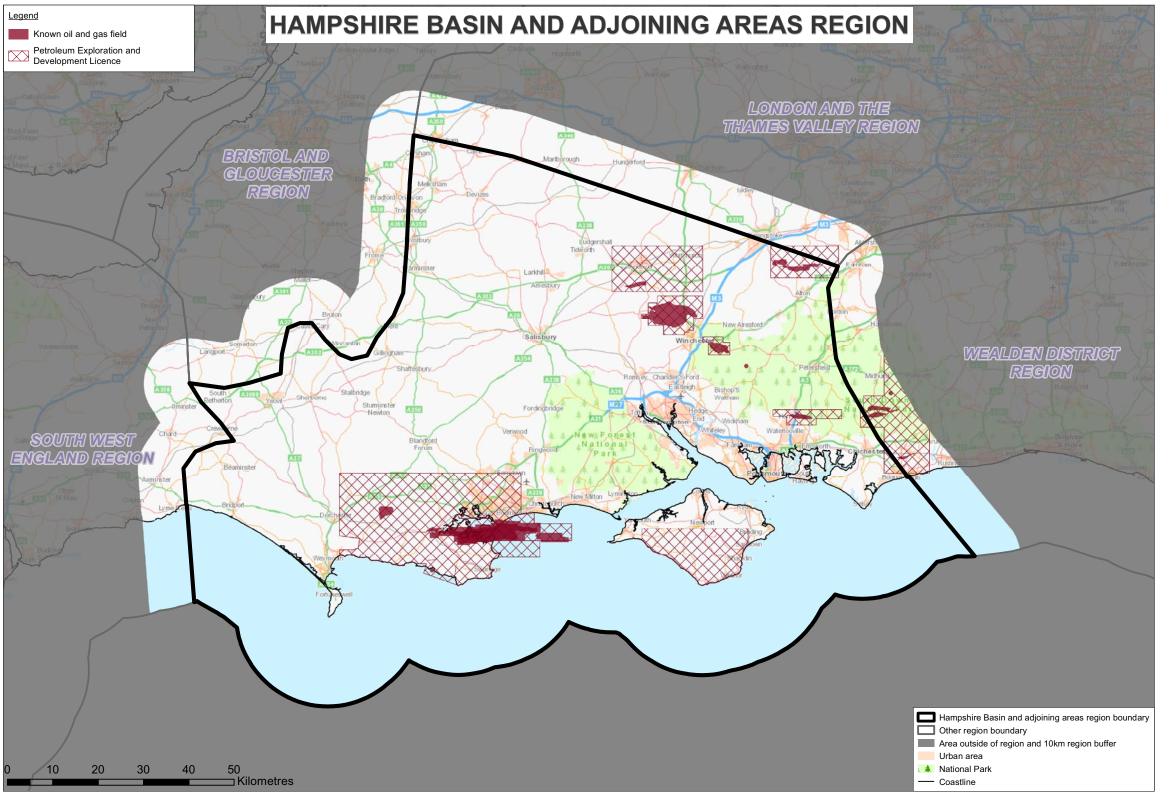
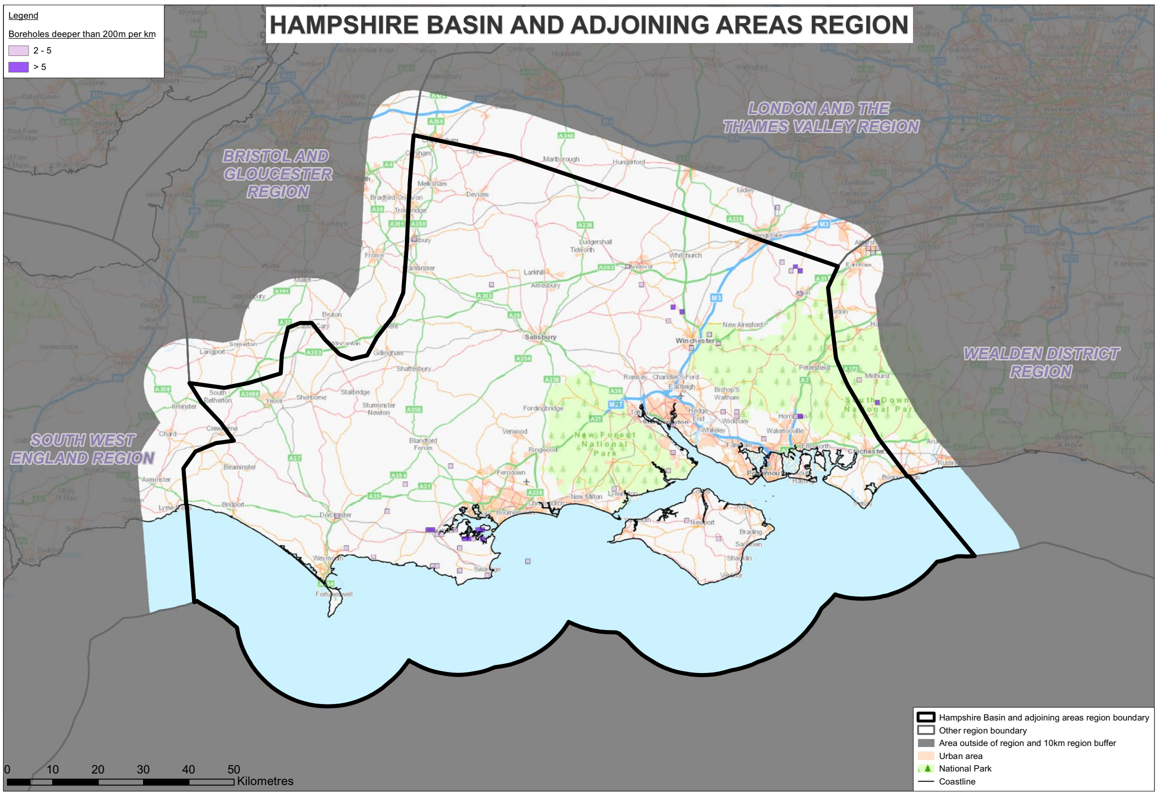


Figure 9 Areas in the Hampshire Basin and adjoining areas region with concentrations of deep exploration boreholes.



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.

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.

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.

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.

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

Lithology
The physical properties of rock types

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

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.

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.

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 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'.

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.

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.

Radioactive Waste Management

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