

South West England

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 comprises the Isles of Scilly, the counties of Cornwall and Devon (including Lundy Island) and the western part of Somerset, west of a line from Bridgwater to Crewkerne. 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 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.

South West England: summary of the regional geology

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

Available information for this region

The surface geology of South West England has been [mapped](#) over many years and is generally well known, with extensive coastal exposures providing valuable observations. Information about the geology at depth is available mainly for the South West England mining district where, in addition to mine records, there are a small number of exploration boreholes and additional [boreholes](#) drilled for geothermal energy. [Geophysical investigations](#), including studies of the Earth's gravity and magnetic fields and [seismic surveys](#), have also been undertaken. These include the [Tellus South West project](#), and results from seismic surveys off the coast in the south-east of the region, in Lyme Bay, and in the Bristol Channel. Gravity studies have helped define the extent of [granite](#) at depth. 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 2 main groups: **younger sedimentary rocks** and **basement** rocks. These are summarised in [Figure 2](#), which has been drawn up to show the oldest and deepest rocks at the bottom of the schematic rock column, with progressively younger rock units towards the top. [Figure 3](#) is a geological map of the region showing where the major rock units occur at the surface. [Figures 4](#) and [5](#) present schematic vertical cross sections through the region. Within the 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 these rocks are likely to be present within the **depth range of interest**.

Younger sedimentary rocks

The youngest rocks occurring in the **depth range of interest** for screening are **sedimentary** rocks of Oligocene to Permian age (approx. 25 to 300 million years old), which occur in the east of the region and off the coast. They are referred to here as the younger sedimentary rocks and comprise sandstones, siltstones, mudstones and limestones with rare **evaporite** sequences. There are several units in the younger sedimentary rock sequence which contain thick mudstones and are likely to behave as **LSSR**. The youngest potential LSSR are Oligocene age sedimentary rocks (around 25 to 35 million years old) found in isolated sedimentary basins along the **Sticklepath Fault** in Devon. Of these, the Bovey Basin, to the east of Dartmoor, is the largest. Older mudstones are present in the depth range of interest in east Devon and in the **inshore** part of the region under the Bristol Channel and Torbay.

It is also possible that there are evaporites with sufficiently thick rock salt (**halite**) layers to act as **Evaporite** host rocks, both in the Bristol Channel and in East Devon.

Basement rocks

A range of rocks form the basement to the **younger sedimentary rocks** that rest on top of them and many of the basement rocks have potential as **HSR** hosts. Rocks of Carboniferous and Devonian age (approx. 300 to 420 million years old) are mainly of sedimentary origin, but with layers of volcanic origin. They have been intensely **folded** and **metamorphosed** in this region, so that the finer-grained varieties are now **slaty**. In this respect, they are more comparable to the Silurian and Ordovician rocks (approx. 420 to 485 million years old) of Wales and northern England than to Devonian and Carboniferous rocks elsewhere. The Devonian rocks (approx. 360 to 420 million years old) of north Devon are distinct from those of south Devon with more abundant sandstones, whereas limestones are important further south. Carboniferous slates and sandstones occupy an east-west trending belt through central Devon into north Cornwall ([Figure 3](#)).



Much of South West England has been intruded by granite, giving rise to a large body extending from east of Dartmoor to the Scilly Isles, known as the Cornubian Granite. Separate granite bodies are exposed at the surface, as on Dartmoor and Bodmin Moor, but [geophysical studies](#) suggest that these granites are likely to be connected at depth. The granite intrusions were emplaced after folding and are surrounded by an [aureole](#) of highly baked metamorphic rock known as [hornfels](#) extending 1 to 3km from the granite contact. In this aureole, slates and sandstones have recrystallised as a result of heating by the granite when it was magma. An isolated and much younger granite body is present in the Bristol Channel, forming Lundy Island. The granites and the surrounding hornfels are potential HSR host rocks.

In the southernmost parts of the region, at the Lizard Peninsula and Start Point, is a complex zone of [igneous](#) and [metamorphic](#) rocks emplaced along faults, which the BGS have identified as potential HSR.

Rock structure

Major [faults](#) and areas of major [folding](#) are shown on the map in (Figure 7). The [unconformity](#) at the base of the Permian sediments is one of the main structural features of the region; it [dips](#) gently east so that in east Devon the geology of the 200 to 1,000m depth range is dominated by the [younger sedimentary rocks](#), while further west basement rocks predominate. The younger sedimentary rocks are gently dipping and there are few faults cutting them, although in some cases they were deposited in fault-controlled basins. The Devonian and Carboniferous basement rocks were folded throughout before the younger rocks were laid down. In many rock units the layers have contrasting mechanical properties and folding is accompanied by faulting and fracturing on a range of scales which is likely to impact on groundwater movement.

There are several types of major fault structures in the region. East-west trending faults have had an impact on the deposition of the sedimentary rocks because they defined the sedimentary basins in which deposition took place. In the south of the region there is also a set of gently-dipping [thrust faults](#) with an easterly to north-easterly trend which are responsible for [juxtaposing](#) the more highly metamorphosed rocks of the Lizard and Start Point against less metamorphosed rocks. The final set of major faults trends in a north-westerly direction and the dominant example is the Sticklepath Fault which crosses the peninsula from Torquay to Bideford Bay and cuts the eastern part of Dartmoor, giving rise to the valley through Bovey Tracy.

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. Although the region contains several **principal aquifers** as well as some local aquifers, over much of the region, water supplies mainly come from surface water sources. The principal aquifers include the Chalk and Inferior Oolite Groups in the east, Sherwood Sandstone Group and Carboniferous Limestone aquifer. Limestone aquifers are also present associated with slaty rocks in south Devon, between Teignmouth and Plymouth.

In the east of the region **LSSR** layers are likely to provide **hydraulic separation** between aquifers and between deep and shallow groundwater, even where they are not thick enough to host a GDF. In much of central and north Devon, together with north Cornwall, the **basement** rocks are often fractured and retain groundwater in open fractures near the surface. These open **fractures** provide a local source of groundwater, but do not persist as open features at depth; water is seldom extracted from deeper than 50m. Groundwater from depths greater than 400m is unlikely to be suitable as drinking water anywhere in the UK¹.

In much of the south and west of the region, granite is present at depth and is also of very low **permeability** with groundwater flow localised through fractures. At Penryn in west Cornwall, deep water flow through fractures in granite was investigated for a pilot geothermal project. Water was injected down deep boreholes into artificially fractured granite at depths of hundreds of metres.

Widespread localised mining in Cornwall and parts of Devon is likely to have changed the original patterns of water movement and shallow groundwater may circulate to greater depths in the range of interest now than it did before mining. However, there are no **thermal springs** 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 range of mineral resources have been exploited in this region including copper, tin, lead and wolfram. The locations of mines below 100m are shown in [Figure 8a](#).

[Petroleum Exploration and Development Licences](#) have been granted for the area between Minehead and Bridgwater in the north-east of the region ([Figure 8b](#)).

The major mining district extended throughout Cornwall, except for the area north of Launceston, and across Dartmoor and although only one mine is currently active, the Drakelands Mine north-east of Plymouth, there are several other prospects in the region ([Figure 8c](#)). The areas of historic copper, tin, arsenic, tungsten and other metal mining shallower than 100m are also shown in [Figure 8c](#).

The granites in this region have relatively high levels of natural radioactivity and so generate more heat than most rocks. As a result, parts of the region have potential for geothermal energy, and attempts were made to exploit it near Penryn in the late 20th century, based on circulating water between boreholes up to 2.6km deep. Interest continues today.

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](#). This region experiences small earthquakes with a similar frequency to the other regions, but there are no particular locations where they are obviously more frequent. The largest known earthquake in the region was a magnitude 4.1Mw earthquake near Penzance in 1757, which was felt from the Scilly Isles to west Devon.

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 beyond the limit of the ice sheets during the [Pleistocene](#) epoch, although it has been suggested that highland-scale glaciation may have affected the upland parts. 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 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

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



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

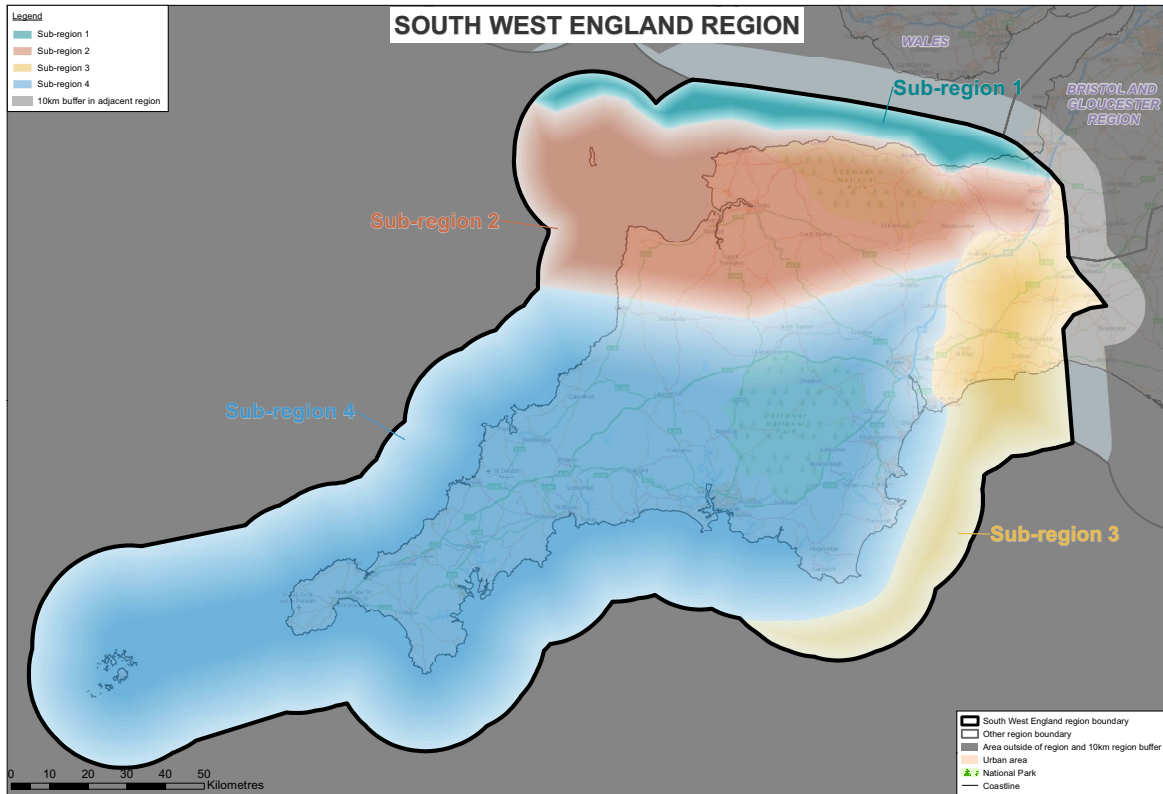




Figure 2 Table illustrating the sequence of the major rock units present in the South West England region, and their possible significance for the siting of a GDF.

	Geological Period (age in millions of years)	Geological Unit	Dominant Lithology	Rock types of interest		
				LSSR	HSR	Evaporite
Younger Sedimentary Rocks	Palaeogene (23.0 – 66.0)	Oligocene sediments	silt, sand, clay, gravel	✓		
		Lundy Island granite	granite		✓	
	Cretaceous (66.0 – 145.0)	Chalk Group	chalk			
		Selborne Group	mudstone, sandstone and limestone			
		Lower Cretaceous sediments including Wealden Formation equivalents	mudstone, siltstone, sandstone, limestone	✓		
	Jurassic (145.0 – 201.3)	Upper Jurassic rocks undifferentiated	mudstone, siltstone, sandstone	✓		
		Ancholme and Corallian Groups	mudstone, siltstone, sandstone and limestone			
		Great and Inferior Oolite Groups	Limestone with mudstone			
		Middle Jurassic undifferentiated	mudstone, sandstone, limestone	✓		
		Lias Group	mudstone with limestone and sandstone	✓		
		Mercia Mudstone Group	Mudstone with siltstone and evaporite deposits of gypsum and halite	✓		✓
		Sherwood Sandstone Group	sandstone with conglomerate and mudstone			
	Permian and Triassic (201.3 – 298.9)	Permian and Triassic undifferentiated	mudstone, siltstone, sandstone with conglomerate	✓		

Basement	Carboniferous to Permian (251.9 - 358.9)	Cornubian Granites	granite		✓	
	Carboniferous (298.9 – 358.9)	Holworthy Group	mudstone and sandstone with siltstone and conglomerate			
		Carboniferous Limestone Supergroup	limestone and mudstone (Quantock Hills only)			
		Teign Valley and Tintagel Groups	mudstone, siltstone and sandstone		✓	
	Devonian (358.9 – 419.2)	Upper Devonian Undifferentiated	slaty mudstone, siltstone, sandstone and limestone		✓	
		Middle Devonian Undifferentiated	slaty mudstone, siltstone, sandstone and limestone		✓	
		Lower Devonian Undifferentiated	slaty mudstone, siltstone and sandstone		✓	
	Devonian and older rocks (Older than 358.9)	Lizard and Start Complex	serpentinite, metamorphosed basic igneous rocks, mica schists		✓	
		Lower Palaeozoic Undifferentiated	Silurian and Ordovician sediments		✓	



Figure 3 Generalised geological map showing the distribution of rock units in the South West 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.

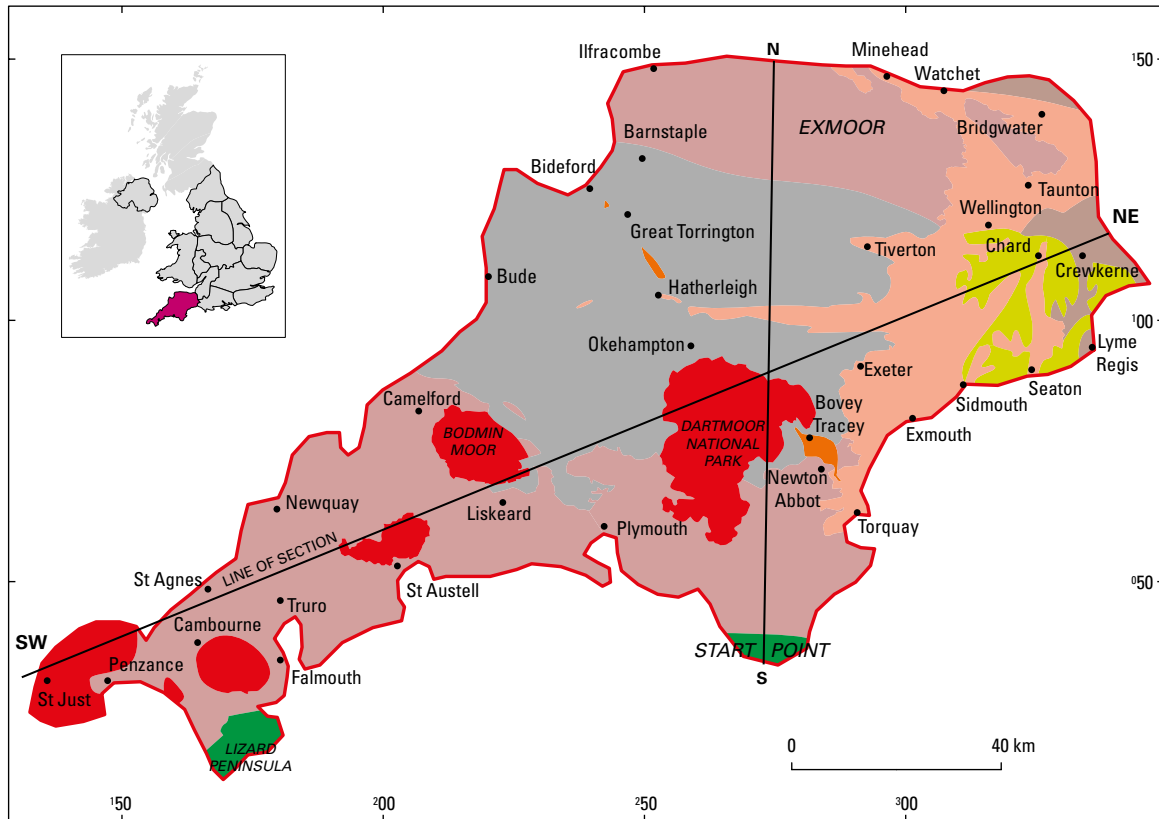




Figure 4 Schematic cross-section south-west to north-east (St Just to Crewkerne) through the South West England region. Line of section is shown in Figure 3. Note that the vertical scale is greatly exaggerated and actual dips of rock layers are much gentler than they appear here. Note also that the underground shape of the margins of the granite bodies (in red) are highly speculative and, as part of a site selection process, we would need to undertake detailed investigations to fully understand their detailed geometry. See Figure 2 for the key to the rock types.

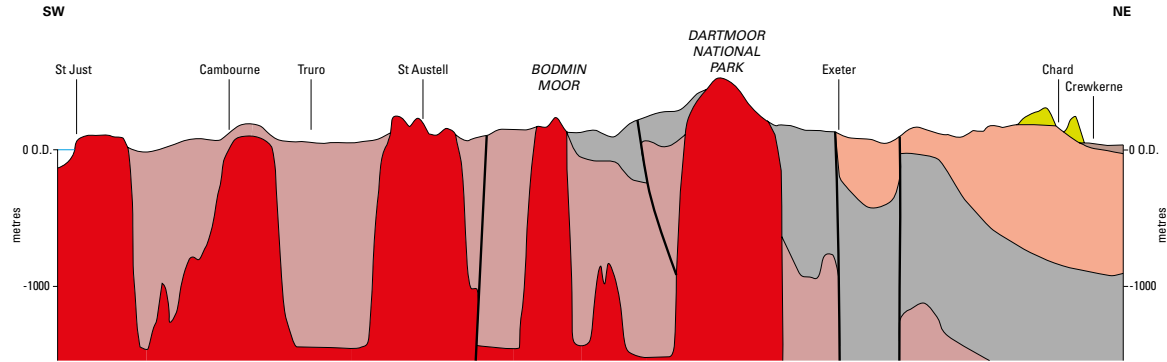


Figure 5 Schematic cross-section north to south (Exmoor to Start Point) through the South West England region. Line of section and key are shown in Figure 3. Note that the vertical scale is greatly exaggerated and actual dips of rock layers are much gentler than they appear here. See Figure 2 for the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

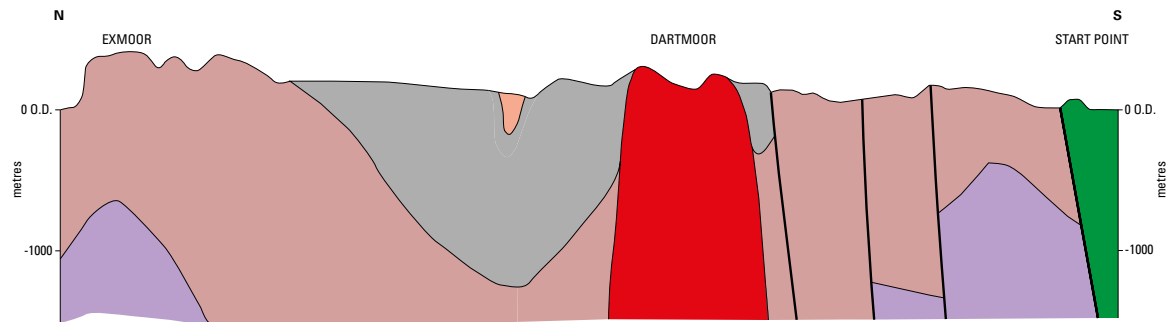




Figure 6a The areas of the South West England region where any of the 3 Rock Types of Interest are present between 200 and 1,000m below NGS datum.

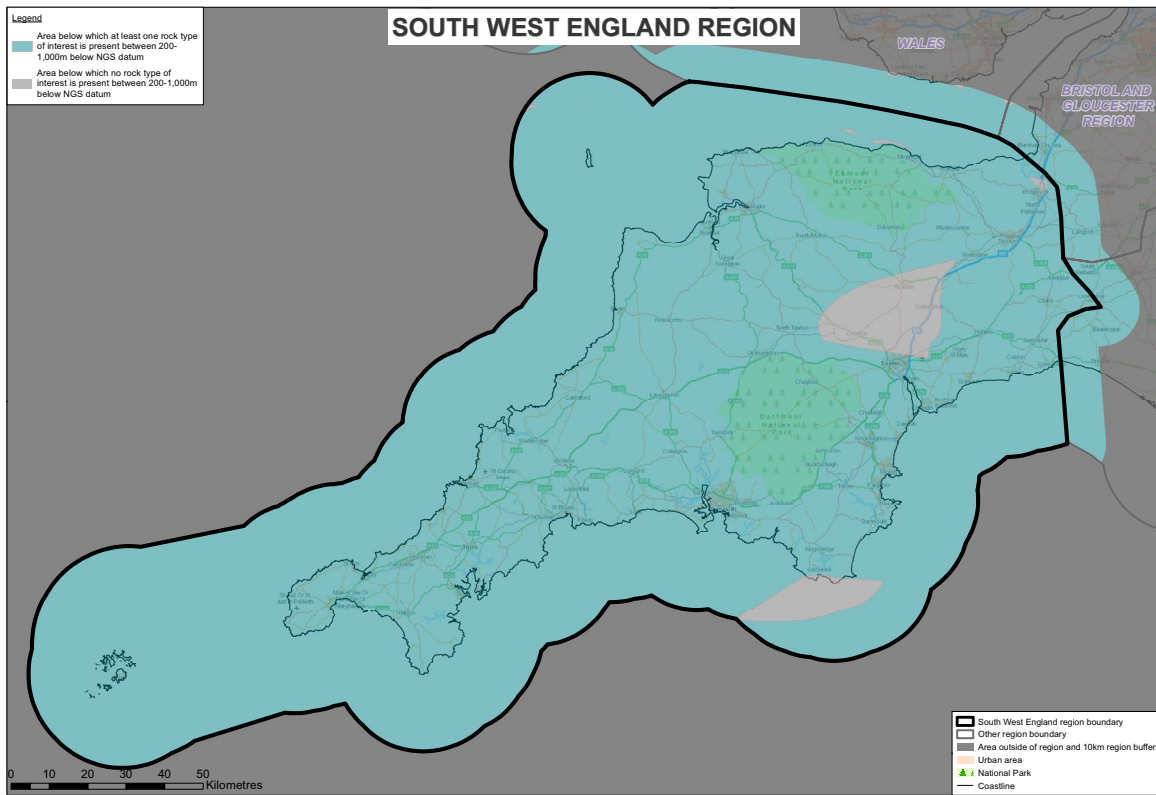


Figure 6b The areas of the South West England region where Lower Strength Sedimentary Rock Types of Interest are present between 200 and 1,000m below NGS datum.

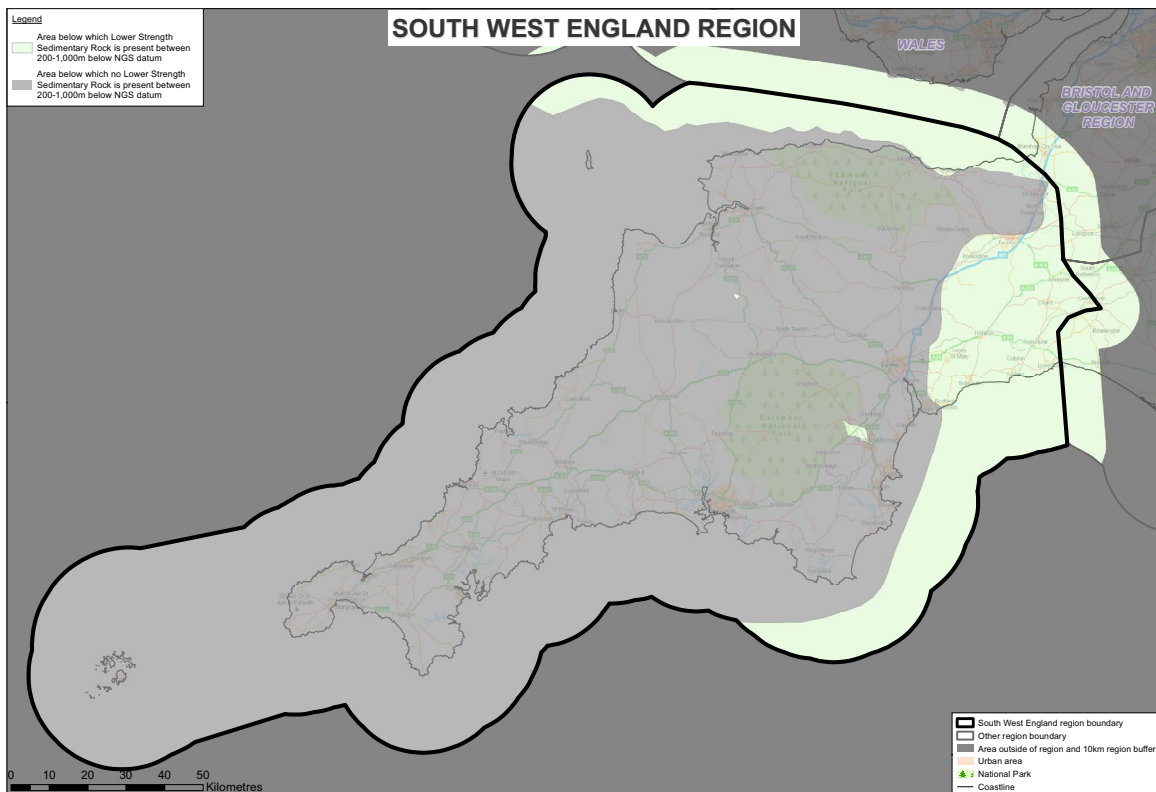




Figure 6c The areas of the South West England region where Higher Strength Rock Types of Interest are present between 200 and 1,000m below NGS datum.

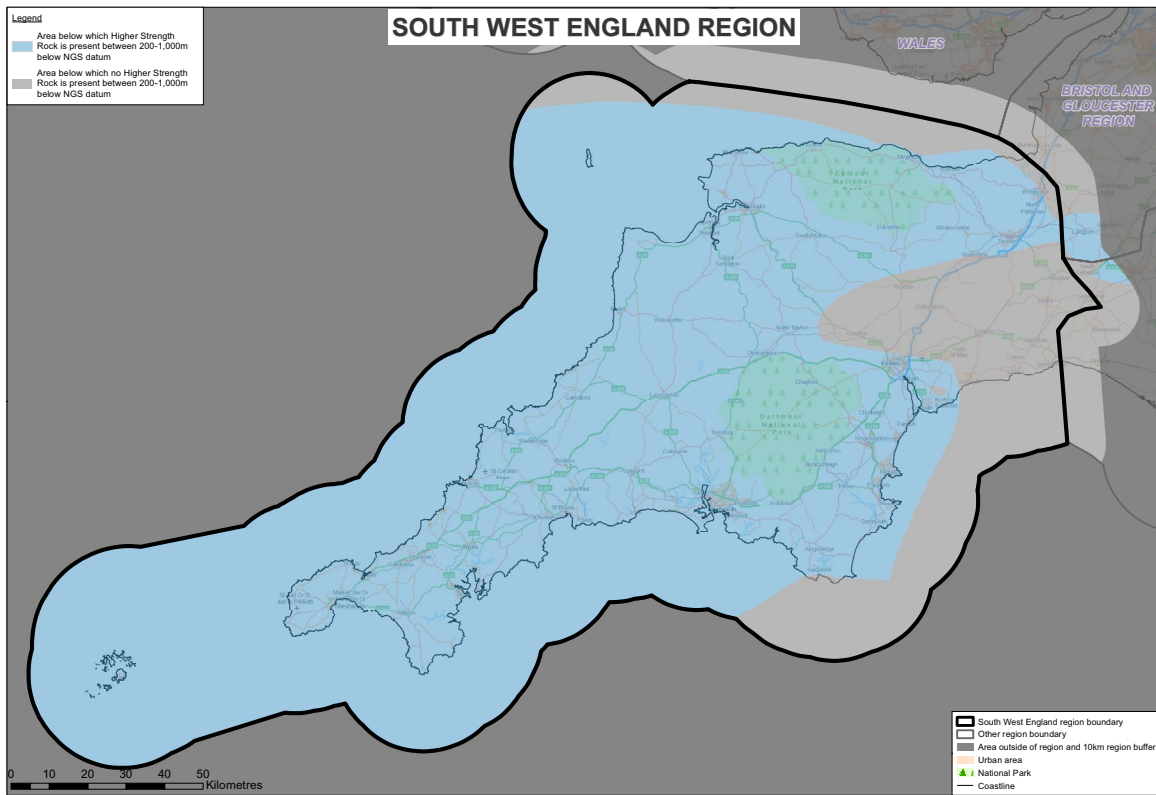


Figure 6d The areas of the South West England region where Evaporite Rock Types of Interest are present between 200 and 1,000m below NGS datum.

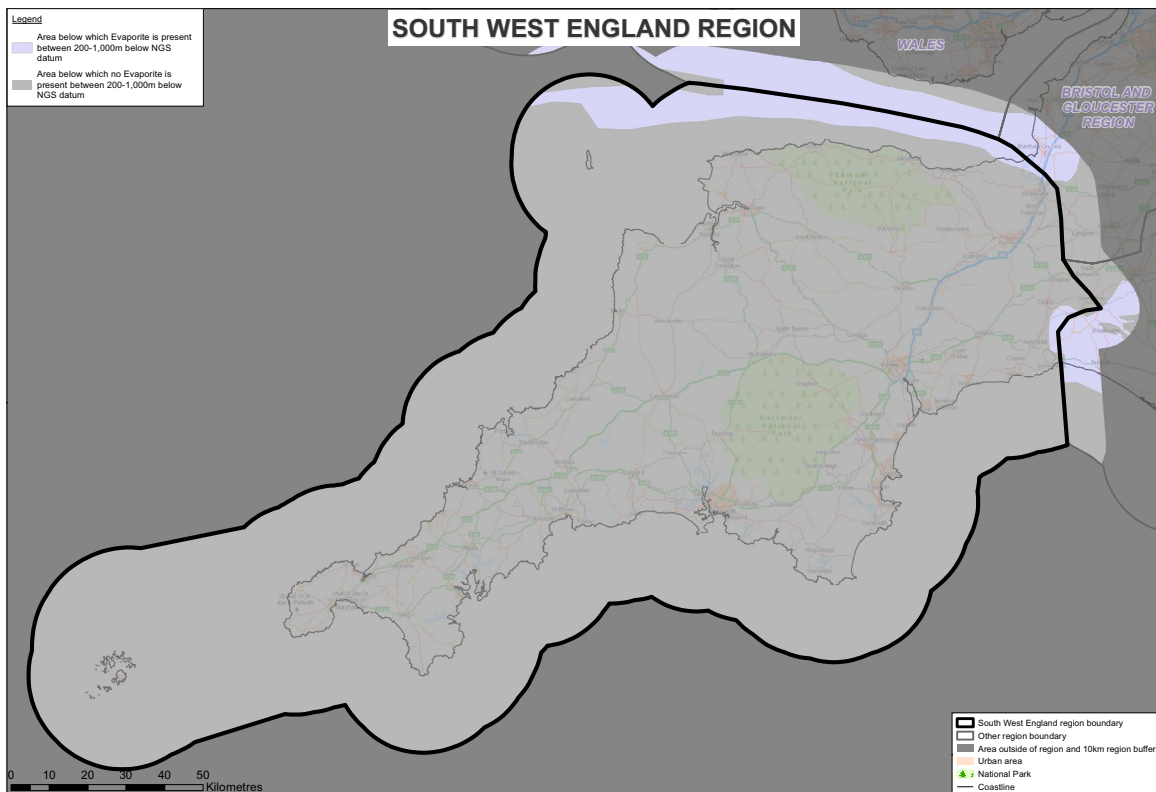




Figure 7 Location of major faults in the South West England region.

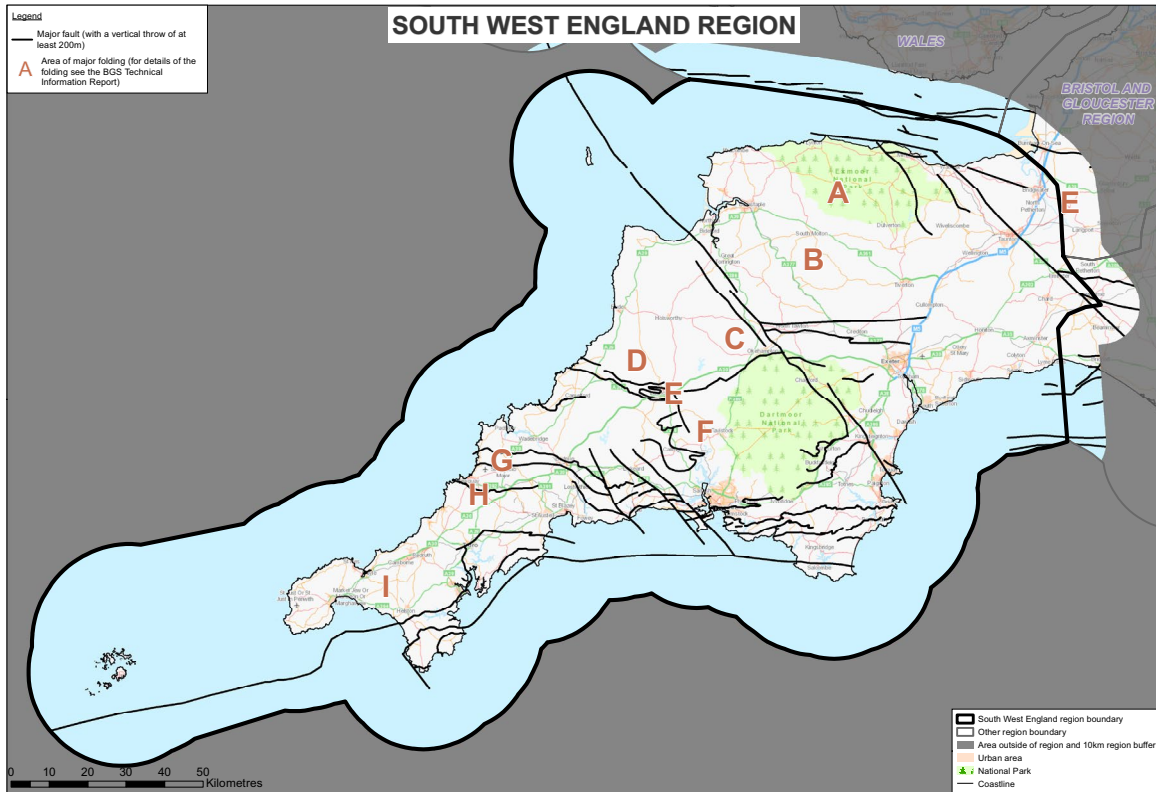


Figure 8a Areas of the South West England region with mines present below 100m.

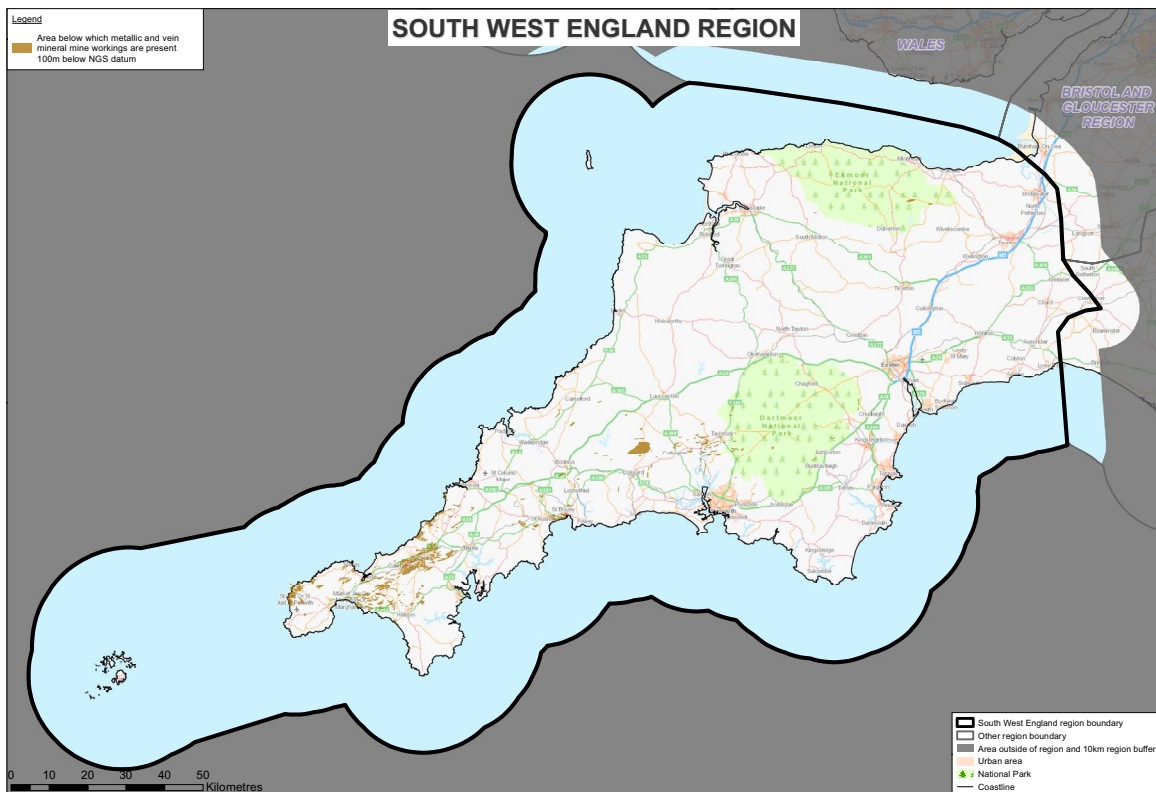




Figure 8b Areas of the South West England region with Petroleum Exploration and Development Licences.

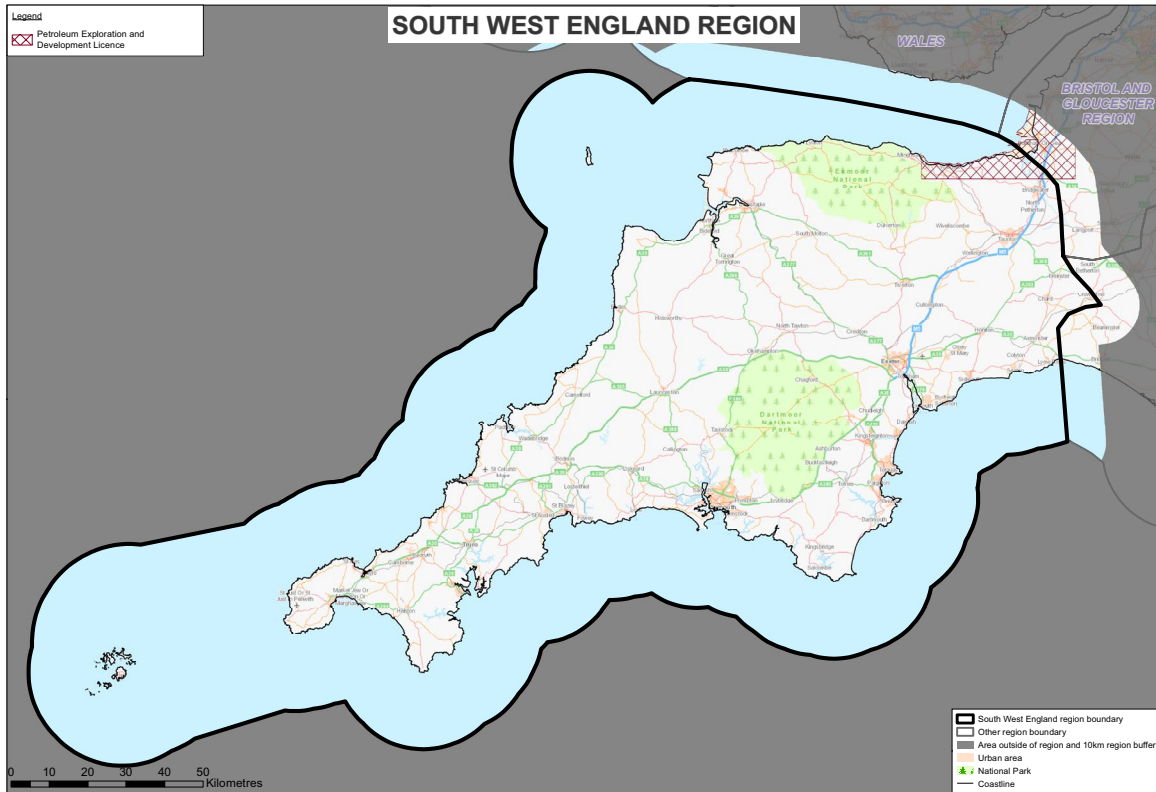


Figure 8c Areas of the South West England region with historical metal ore mines less than 100m deep and known mineral prospects.

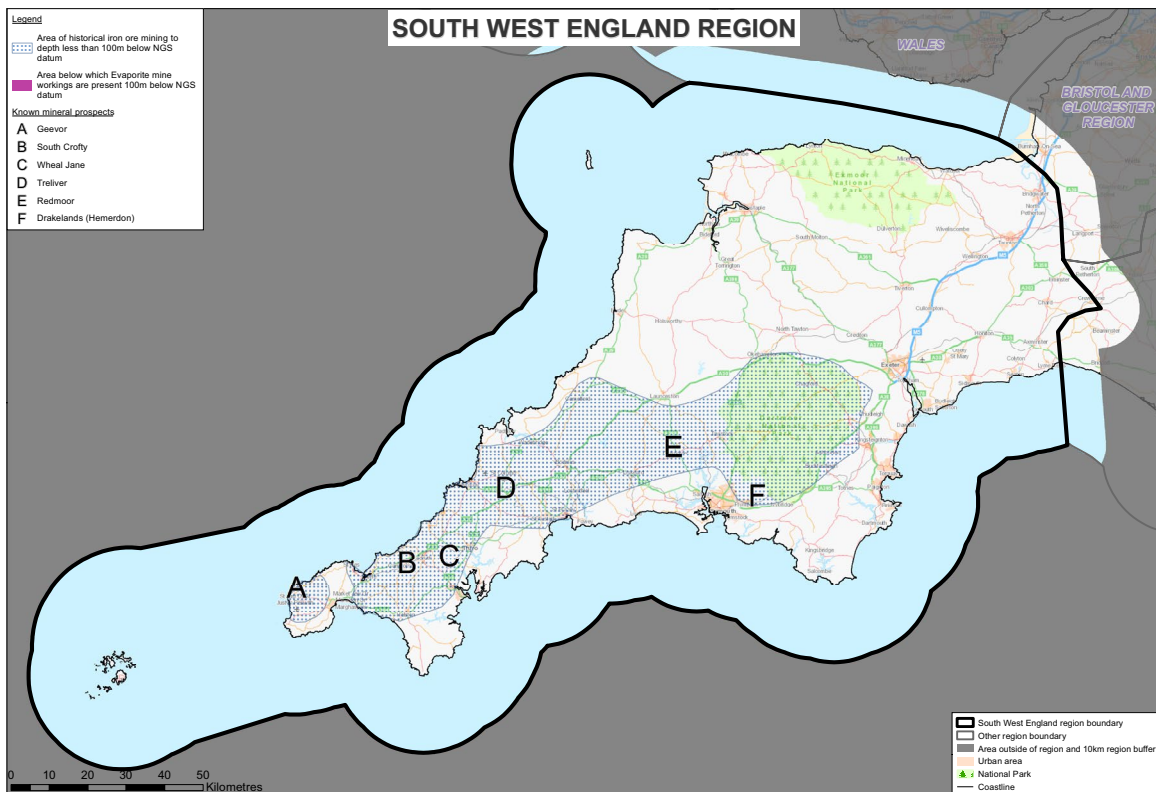
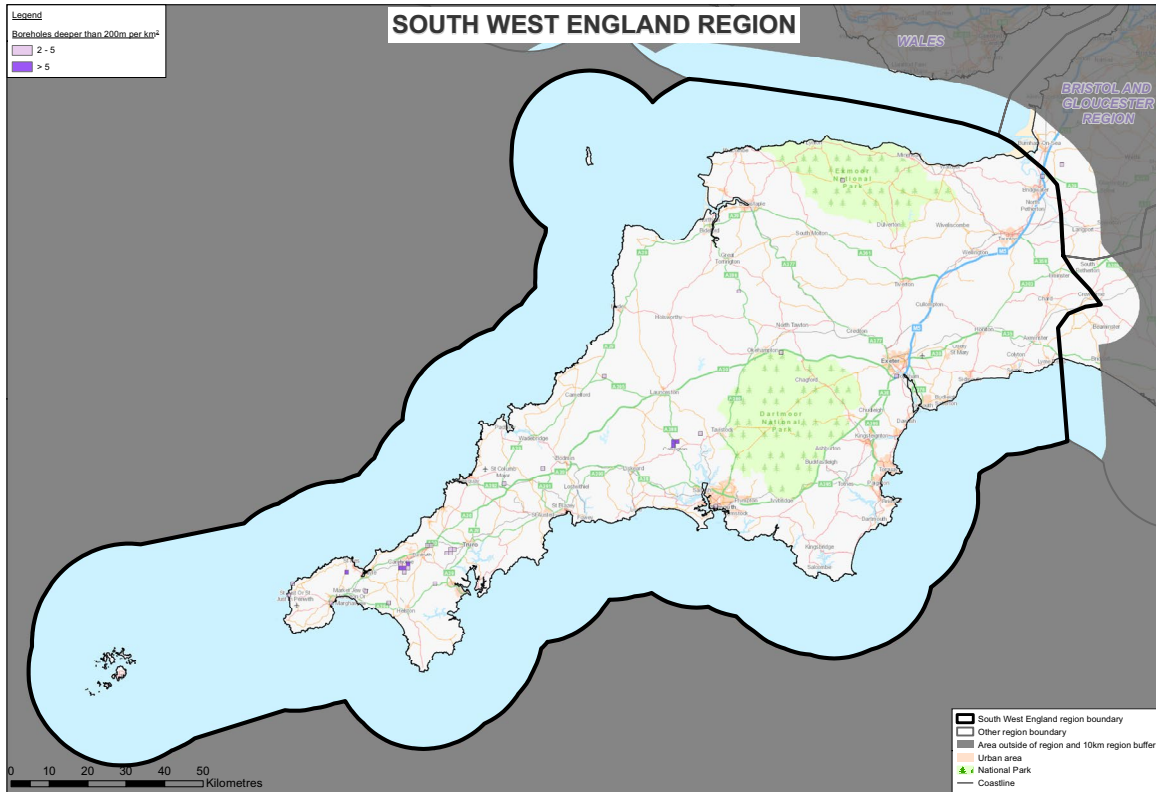




Figure 9 Areas in the South West England region with concentrations of deep exploration boreholes.





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.

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.

Aureole

A zone of baked and altered rock surrounding a formerly hot magma intrusion, where the heat has recrystallized the existing rocks.

Dip

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

Erosion

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

Evaporite

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.

Fracture

A crack in rock. Fractures can provide a pathway for fluids, such as groundwater or gas, to move in otherwise impermeable rock.

Granite

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

Halite

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

Hornfels

A metamorphic rock formed when a hot igneous body is intruded into a sedimentary rock. The heat from the igneous intrusion causes the mineral composition of the sedimentary rock to change. The crystals in a hornfels are fine grained and non-aligned.

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.



Glossary

Juxtaposing

When two features are positioned side by side. Different rock types can often be juxtaposed across faults and unconformities

Lithology

The physical properties of rock types.

Metamorphic/metamorphosed

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

Pleistocene

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

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.

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.

Slaty

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

Thrust faults

A type of fault, or break in the earth's crust that forms due to the action of compressive forces.



Radioactive Waste Management

Building 587
Curie Avenue
Harwell Oxford
Didcot OX11 0RH

T 03000 660100
www.gov.uk/rwm