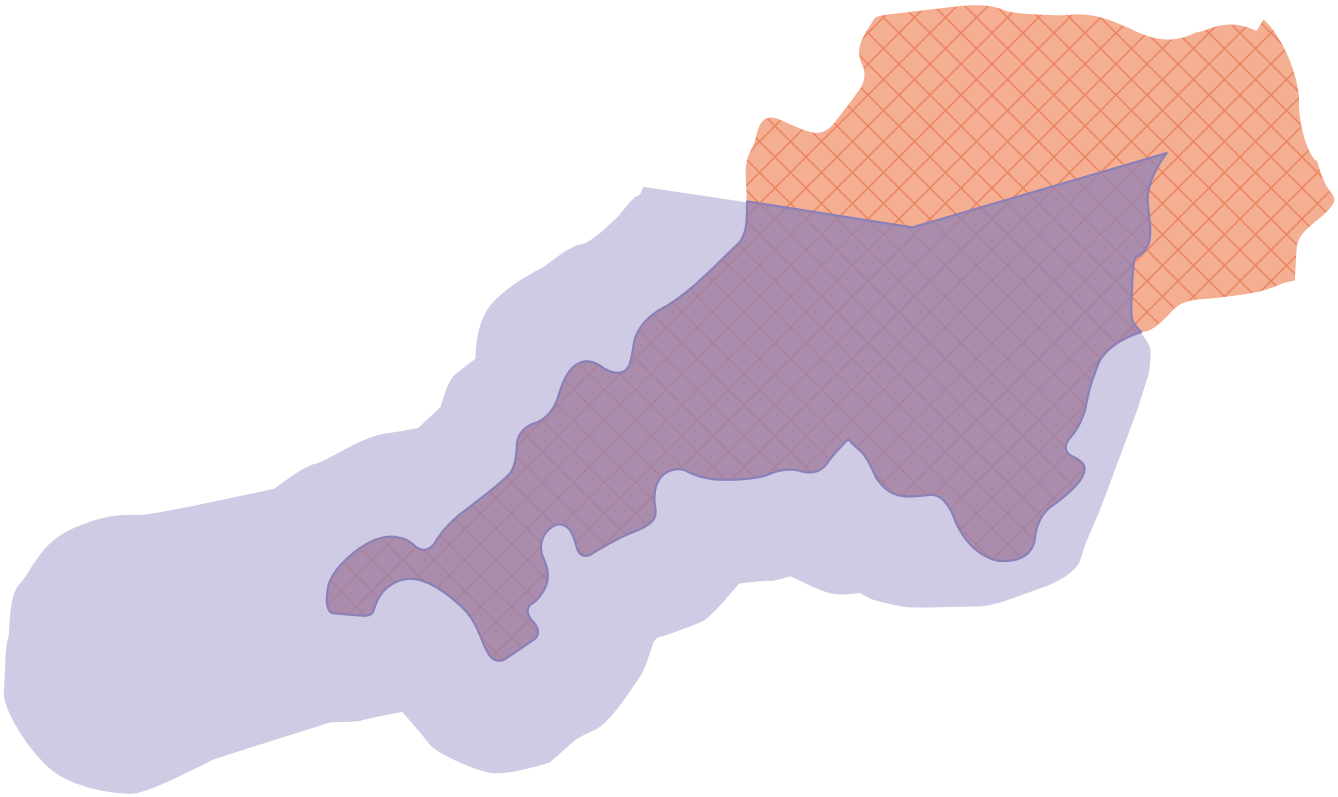
Radioactive Waste Management



South West England

SUBREGION 4

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.

Our work shows that we may find a suitable geological setting for a GDF in most of this subregion, but the properties of the potential host rocks present may not be suitable.

Rock can be seen at the surface over much of the subregion including the extensive sea cliffs, inland rock tors on Bodmin and Dartmoor and man-made excavations such as quarries or road cuttings. Combined with deep boreholes and some geophysical investigations, this gives us an understanding of the rocks present and their distribution.

There are granites, slates and similar strong rocks under most of the subregion in which we may be able to site a GDF. We would need to do more work to find out whether these rocks have suitable properties and thicknesses.

Some of the subregion has been mined to depths below 100m for tin, copper, arsenic, lead and other metal resources, in particular West Penwith, north of Lands End, between Penzance and Truro, around St Austell and north of Liskeard. In these areas the mining is likely to have affected the way in which water moves through the rock. Also possible exploration in the future in these areas means that it is more likely that future generations may disturb a facility.

Introduction

This subregion extends from the Scilly Isles in the west to near the M5 motorway and River Exe estuary in the east. It includes the adjacent inshore area which extends to 20km from the coast. The northern limit approximates to a line from Bude to Tiverton.

Rock type

Figures 1a to 1c shows where in the subregion there are likely to be Rock Types of Interest within the depth range of interest between 200 and 1,000 m below NGS datum. The geology of this subregion is mainly known from surface mapping, but there has been widespread mining with associated deep boreholes in the west of the subregion and some geophysical surveys have been carried out. The geology of the depth range of interest is dominated by 4 main groups of basement rock:

- Carboniferous rocks (approx. 300 to 360 million years old). There are few boreholes and the distribution of the different rock units at depth is not well known. Many of these rocks contain frequent sandstone layers, interbedded with slates on a scale of a few metres and are pervasively folded throughout, often with faults and fractures linked to the folds. As a result they are unlikely to be suitable to host a GDF. However, the Lower Carboniferous Teign Valley Group and Tintagel Group are more uniform and are potential Higher Strength Rocks (HSR). In these groups, slaty mudrocks predominate, with more siliceous cherty mudrocks and occasional limestones above and slaty mudrocks with metamorphosed volcanic rocks below.
- Devonian rocks (approx. 360 to 420 million years old). There is considerable variation in detail across the subregion but the Devonian rocks may be hundreds to thousands of metres thick; high quality Upper Devonian slates have been quarried in north Cornwall, between Launceston and Tintagel. Middle Devonian and Lower Devonian slates are also present in the 200 to 1,000m depth range across the southern part of the subregion, and locally include volcanic rocks. These slates may act as a barrier to groundwater movement and have the potential to act as HSR host rocks, where they are sufficiently thick. The Devonian rocks in the South Hams are unlikely to be suitable because interbedded limestones and slates are sandwiched between repeated thrust faults.
- Granite. The Cornubian Granite Batholith (approx. 280 million years old) underlies the central and south-western parts of this subregion and granite occurs at the surface on Dartmoor and Bodmin Moor, as well as in parts of west Cornwall and the Scilly Isles. Granite is also sometimes present within the depth range of interest between these areas of outcrop. Much of the Cornubian batholith is composed of granite that has been little altered since it formed, but there are zones of faulting and fracturing and areas where extensive hydrothermal alteration has formed china clay deposits. The granite is often surrounded by haloes of baked and very hard metamorphic rocks in which the adjacent Devonian and Carboniferous basement rocks were heated by the intrusions and recrystallized. The unaltered granite and the surrounding metamorphic rocks are potential HSR host rocks.

- A further group of metamorphic rocks occurs in the south of the subregion on the Lizard Peninsula and near Start Point. These are of Devonian age in part (approx. 360 to 420 million years old), although some older rocks are probably also present. They include mica schists and metamorphosed basaltic rocks together with the large serpentinite body of the Lizard, and occur in a structurally complex zone with many faults on all scales. Although these rocks are intensely fractured at outcrop, they may be potential HSR within the depth range of interest if larger masses of relatively uniform rock are present.

In addition to the basement rocks described above, there is a small sedimentary basin near Bovey Tracy which may contain sufficient thicknesses of clay-rich Eocene to Oligocene rocks (approx. 25 to 55 million years old) to act as Lower Strength Sedimentary Rock (LSSR) hosts. There is very limited information available at depth in this basin and it is not known if these rocks extend into the depth range of interest.

A summary of the geological attributes of the South West England region can be found here, including a simplified rock column showing the oldest and deepest rocks at the bottom, with progressively younger rock units towards the top.

Rock structure

There are several major faults and areas of intensive folding across much of this subregion (Figure 2). The major faults include gently-dipping thrust faults in the south that juxtapose the metamorphic rocks of the Lizard and Start Point against the slates and sandstones to the north and the Sticklepath Fault which cuts south-east to north-west through the subregion and has deep sedimentary basins along it. Faults may act as barriers to or pathways for groundwater movement, depending upon their characteristics, and these would need to be considered during the siting of a GDF[1].

The Devonian and Carboniferous rocks are intensively folded with most of the folds aligned east-west. As a consequence of this folding the dip of the rock layers varies considerably over short distances and this would complicate the search for volumes of uniform rock 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. There are several principal aquifers in the east of the subregion including the Sherwood Sandstone Group and Devonian Limestones. Flow in these limestones is karstic, where weakly acid groundwater has dissolved the limestone leading to enlargement of natural fracture systems and the formation of a connected network of fissures and caves. Groundwater from depths greater than 400m is unlikely to be suitable as drinking water anywhere in the UK[2].

Groundwater flow in the basement sandstones and slates is likely to be dominated by fractures, often related to faults and folds, and mainly occur within a few tens of metres of the surface; water from these rocks is mainly extracted from wells that are no more than 50m deep.

Within the granite there is additional information from deep mines and from geothermal exploration boreholes near Penryn. Deep groundwater is sometimes saline and there is evidence of warm water derived from below 1,000m entering mine workings at South Crofty, near Camborne.

There are no low permeability clay-rich rock layers in most of this subregion to act as barriers to vertical flow between deep and shallow groundwater.

In parts of the subregion mining is likely to have changed the original patterns of water movement and shallow groundwater may now circulate to greater depths within the depth range of interest than it did before mining. There are also some areas in the subregion, around Camborne in particular, where deep exploration boreholes may influence the connectivity between shallow and deep groundwater which would need to be considered during the siting process (Figure 3). There are no thermal springs in this subregion to suggest rapid flow of deep groundwater to the surface.

[1] 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. We recognize the potential importance of smaller scale faults to the integrity of a GDF and will need to survey them in detail as part of the site evaluation process.

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

Resources

Tin, copper, arsenic, lead and other metals have been mined extensively in the south-west England mining district below 100m (Figure 4a). In these areas mining is likely to have affected the way in which water moves through the rock. Also possible exploration in the future in these areas means that it is more likely that future generations may disturb a facility. These known resources would be taken into account in the siting of a GDF.

This subregion is the most important metal mining district in the UK and one where mining and exploration continue today. Drakelands tungsten/tin mine, north-east of Plymouth, which commenced full operation in 2015 is currently an open pit mine, but is expected to reach a depth of 200m once surface mining has been completed. The extent of the orefield and the location of specific known prospects are shown on Figure 4b. The mineralisation is in veins occupying faults and fractures and its occurrences are less readily predicted than bedded resources such as coal. Both the granite and the surrounding slates are extensively mineralised in some parts of the subregion, but there are also large areas where there is no evidence that ore deposits are present.

This subregion is also an area with potential for exploitation of geothermal energy, and trials were carried out at Rosemanowes Quarry, near Penryn, in the 1970s to 1980s and interest continues. Extraction of geothermal heat involves circulation of water through artificially stimulated fractures in the granite and so would have to be considered in the siting of a GDF.

Natural processes

Earthquakes and glaciations are unlikely to significantly affect the long-term safety of a GDF in the UK. Therefore, whilst a GDF would need to be sited and designed to take account of natural processes which may occur during its lifetime, they are not considered further as part of this screening exercise.

Figure 1a The areas of the South West England subregion 4 where any of the 3 Rock Types of Interest are present between 200 and 1,000 m below NGS datum.

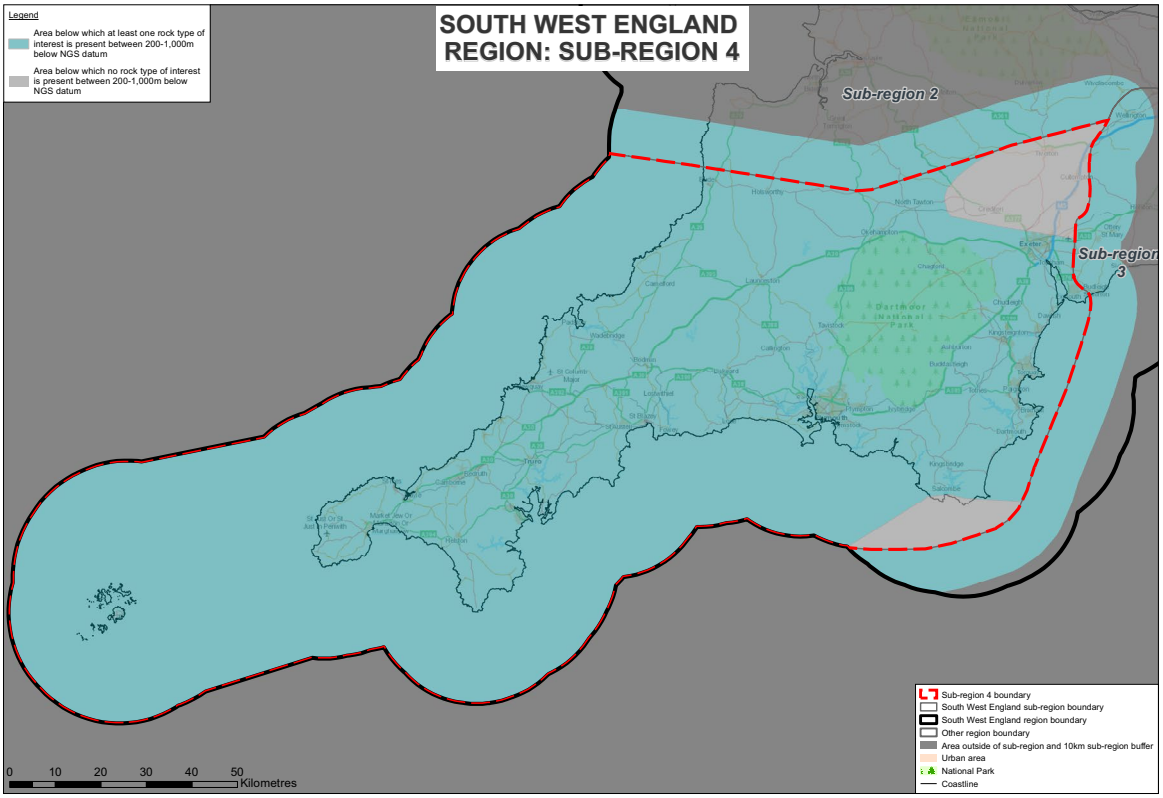


Figure 1b The areas of the South West England subregion 4 where Lower Strength Sedimentary Rock Types of Interest are present between 200 and 1,000 m below NGS datum.

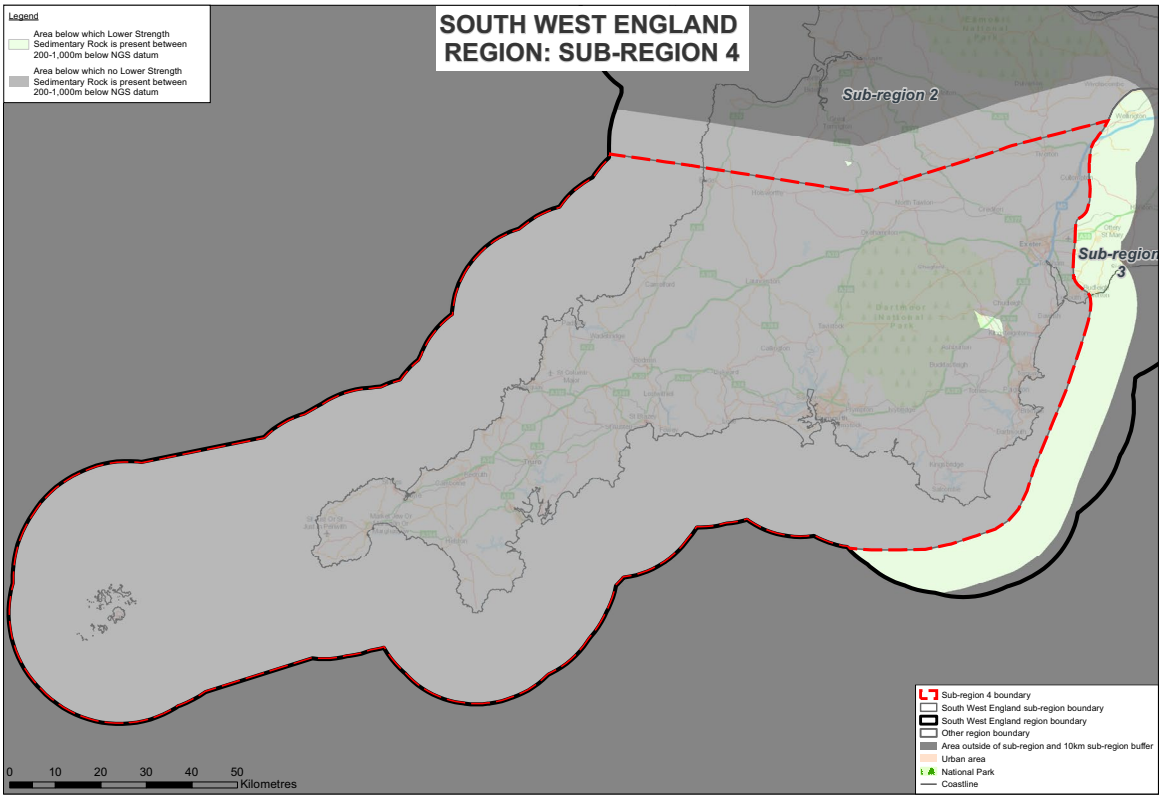


Figure 1c The areas of the South West England subregion 4 where Higher Strength Rock Types of Interest are present between 200 and 1,000 m below NGS datum.

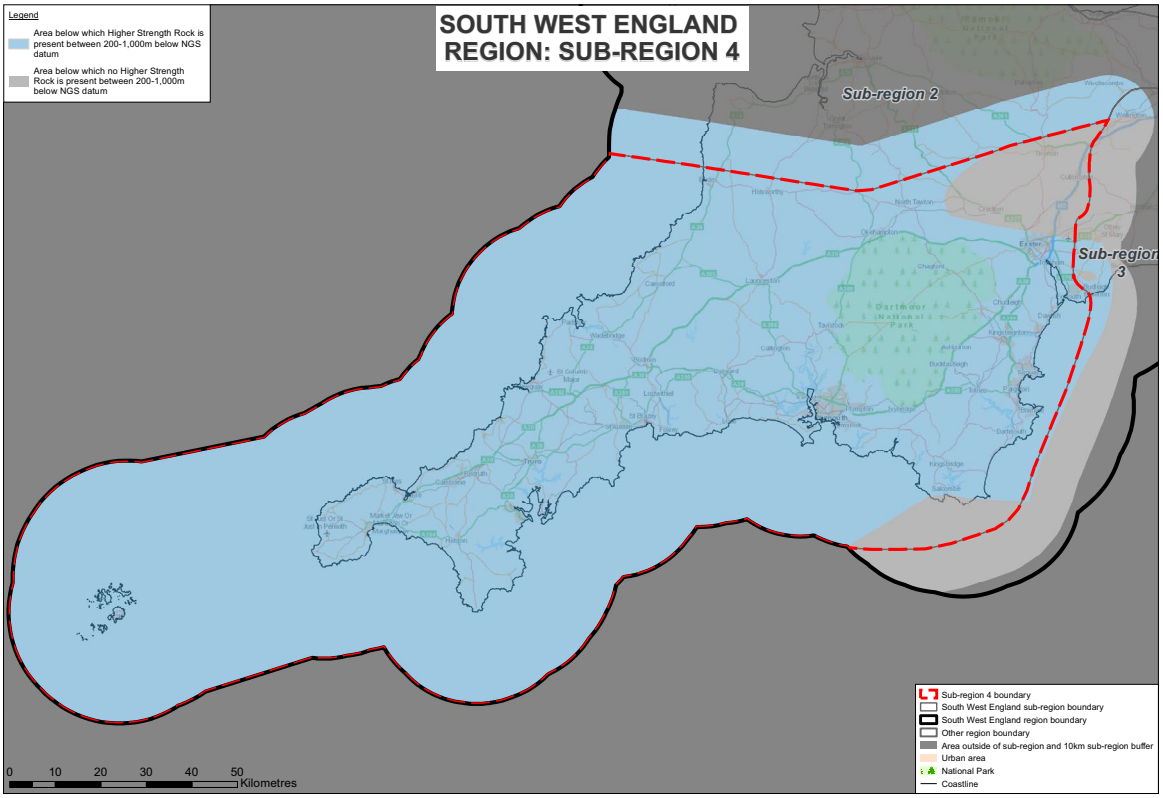


Figure 2 Location of major faults in the South West England subregion 4.

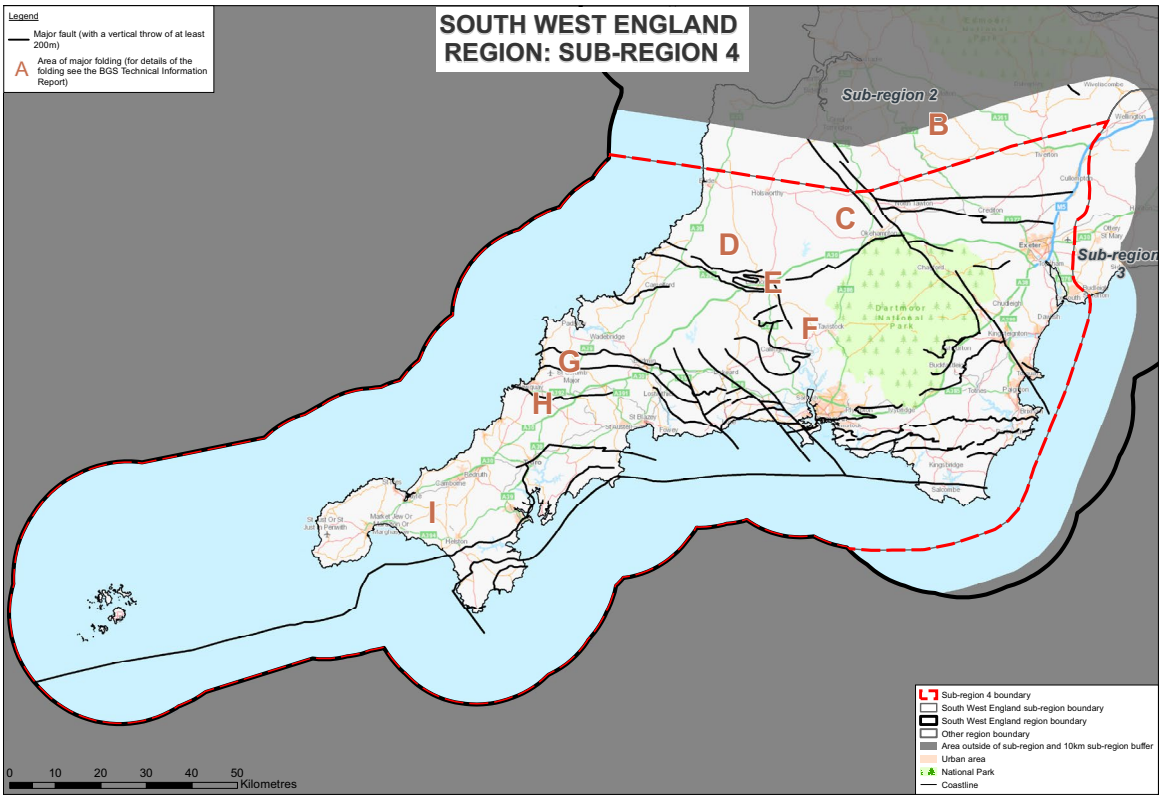


Figure 3 Areas in the South West England subregion 4 with concentrations of deep exploration boreholes.

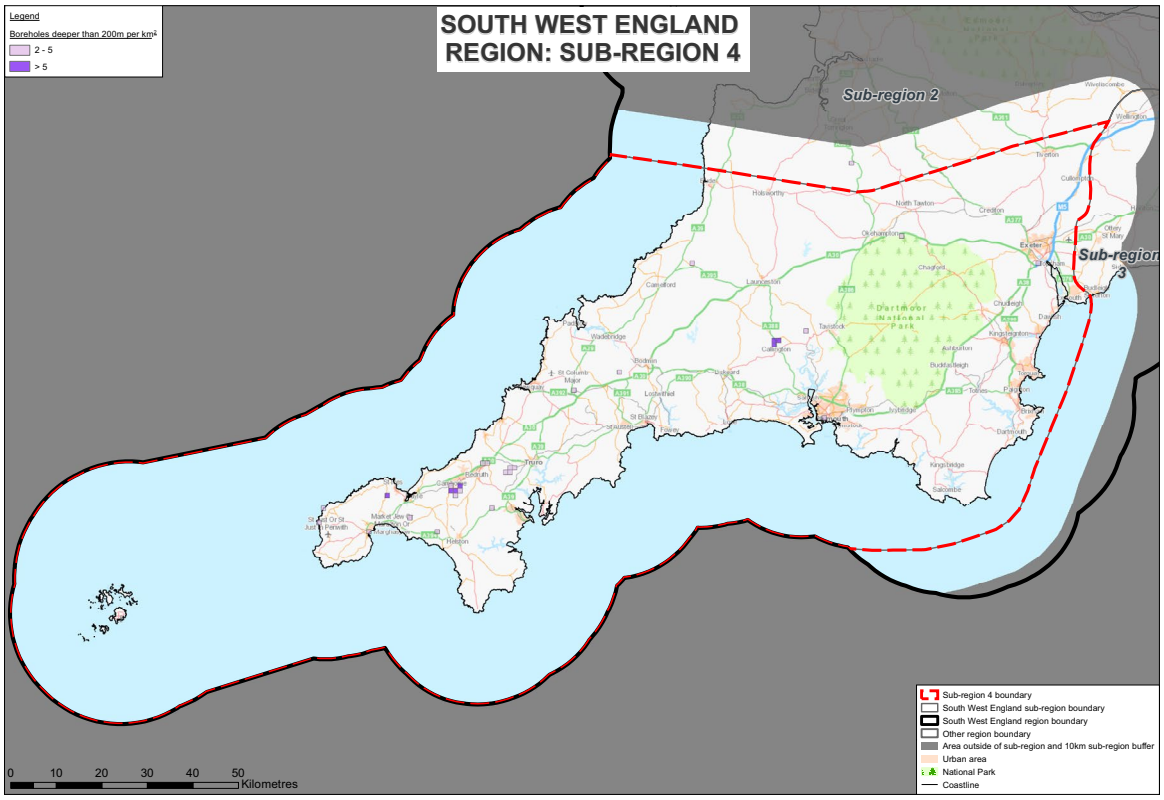


Figure 4a Areas of the South West England subregion 4 with mines present below 100m.

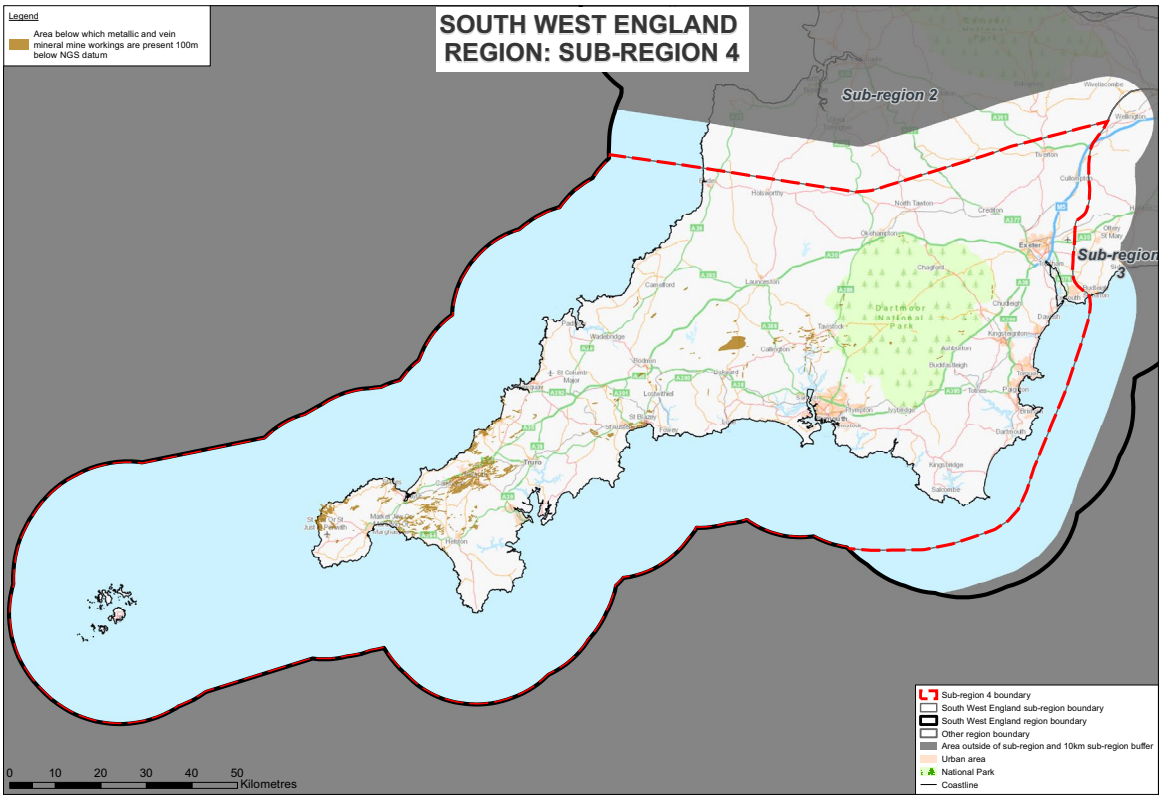
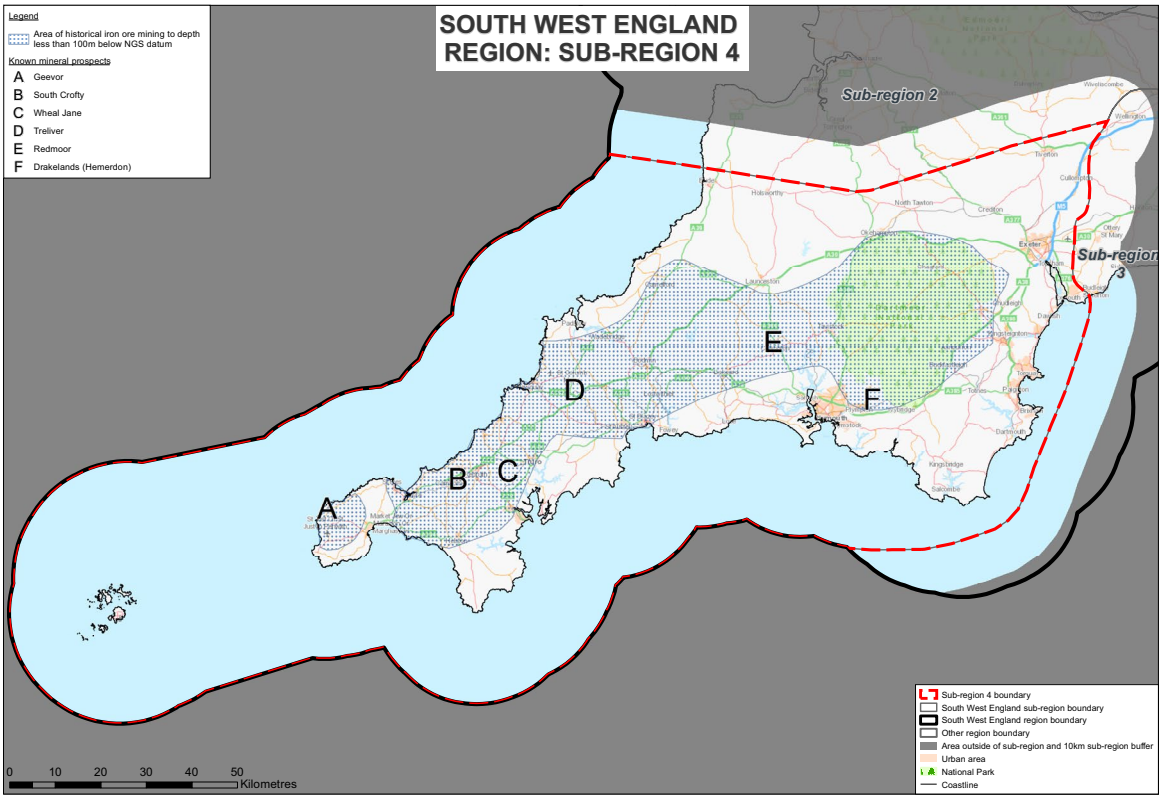


Figure 4b Location and extent of the historical orefield and known prospects in the South West England subregion 4.



Glossary

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.

Basalt
Dense, dark-coloured lava rich in iron and magnesium. Forms during non-explosive eruptions of shield volcanoes, often in oceanic islands such as Hawaii.

Batholith
Large igneous intrusion that has cooled to form a mass of igneous rock, often granite. Dartmoor is a good example.

Chert
A hard rock made of microscopic silica crystals.

China clay
A rock commonly used in the production of ceramics. It is predominantly made of the clay mineral kaolinite.

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

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.

Geothermal exploration boreholes
Deep boreholes often several thousand metres depth that have been drilled in the search for hot rocks from which water can be pumped to the surface and used to generate electricity.

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

Hydrothermal alteration
The alteration of a rock's mineralogy due to contact with hot water-rich fluids within the earth's crust.

Karst
A distinctive type of landscape consisting of deep cracks and caves in limestones. Karst forms due to the action of mildly acidic groundwater dissolving the limestone.

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

Mica schists
Finely layered metamorphic rock that is abundant in the mica-group of minerals.

Outcrop
A visible exposure of bedrock on the surface.

Glossary

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.

Serpentinite
A highly fractured metamorphic rock that forms when hot water circulates deep beneath ocean basins.

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.

Vein
Veins are sheet-like bodies of minerals that have been intruded into fractured rock. Commonly they are made up of quartz or calcite crystals but can also contain small concentrations of zinc, lead, silver and other precious metals.

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