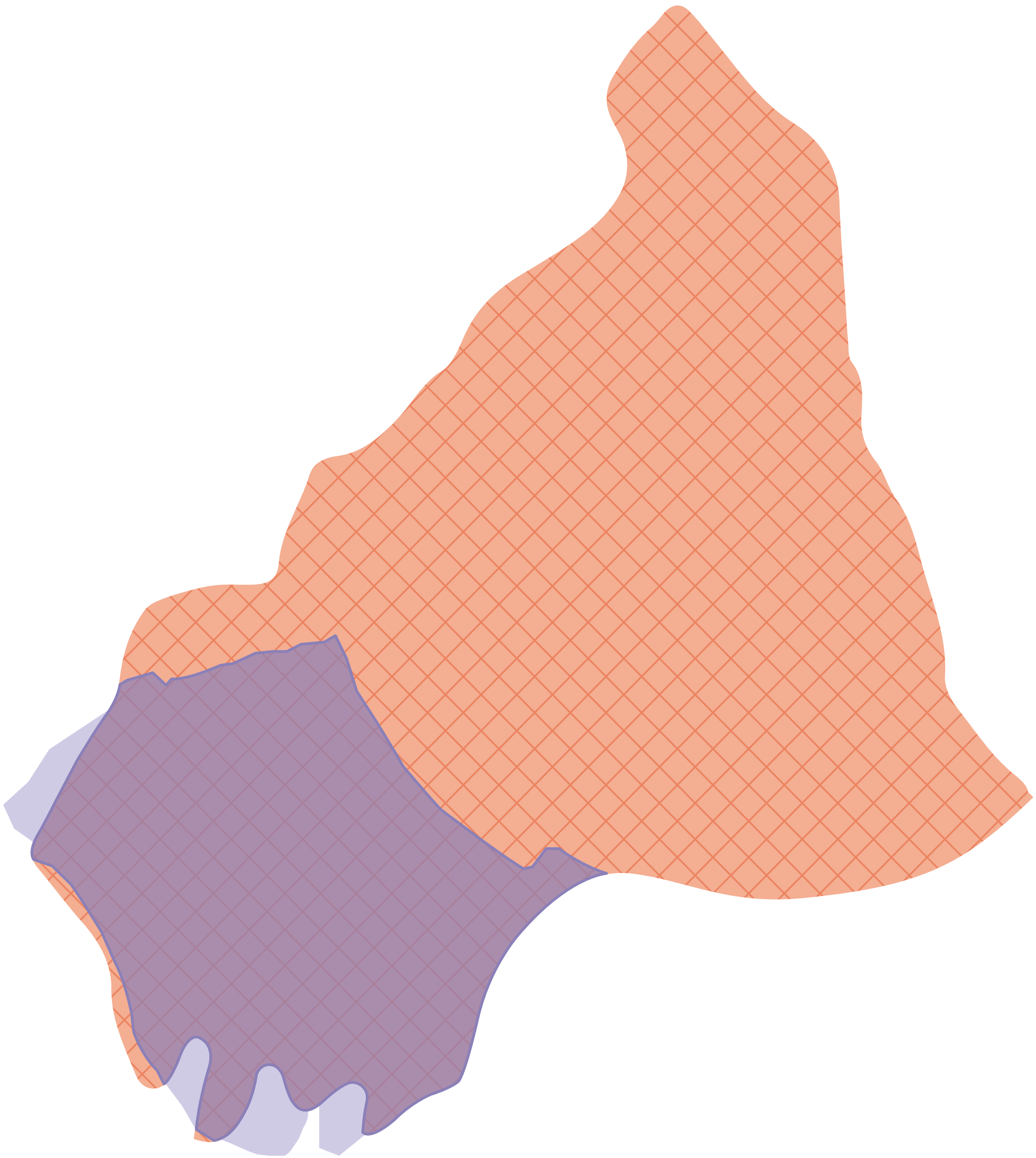
Radioactive Waste Management



Northern England

SUBREGION 3

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.

Rock can be seen at the surface in cliffs, river gorges and man-made excavations such as quarries or road cuttings over much of this subregion. Combined with some deep boreholes and geophysical investigations, this gives us an understanding of the rocks present and their distribution.

There are granites, slates, volcanic lavas 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 in the depth range of interest for a GDF.

Some of the subregion has been mined to depths below 100m for coal resources, from Whitehaven through Workington and Maryport to north of Cockermouth, iron, around Egremont and Barrow-in-Furness, copper, around Coniston and Glenridding, and lead, around Glenridding. 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.

Part of this subregion, around Barrow-in-Furness, has Petroleum Exploration & Development Licences to allow companies to explore for oil and gas. This exploration is currently at an early stage and it is not known whether oil or gas in these licence areas will be exploited. RWM will continue to monitor how this exploration programme progresses.

Parts of this area, off the coast of Whitehaven, are Coal Authority Licence Areas allowing companies to explore for coal. It is not known if coal in these licence areas will be exploited. RWM will continue to monitor how this exploration programme progresses.

Part of the subregion which was mined for anhydrite and gyspum, around Whitehaven, would also need to be taken into account in the siting of a GDF, although the nature of mining in evaporites does not affect the movement of groundwater in the surrounding rocks in the same way as other mining.

Introduction

The Northern England subregion 3 comprises the upland areas of Cumbria extending from south of Carlisle west to Workington and Whitehaven, south-east to Millom and Carnforth and north-east to Kirby Stephen.

Rock type

Figure 1 shows where in the subregion there are likely to be Higher Strength Rocks (HSR) within the depth range of interest, there are no Lower Strength Sedimentary Rocks (LSSR) or Evaporites in the subregion. There are 4 main types of basement rock with potential to act as HSR host rocks:

- The Windermere Supergroup of Silurian age (approx. 420 to 445 million years old) comprises rocks of sedimentary origin with some interbedded volcanic rocks. The layers are often steeply dipping, so that rocks in the depth range of interest for screening are similar to those at the surface above. Within this group, there are 2 groups, the Kendal Group and the Dent Group, which have potential as Higher Strength Rock (HSR) host rocks. The Kendal Group is up to 4,500m thick and has been intensely folded and metamorphosed so that the mudrocks have become slaty. Its physical properties are likely to be relatively uniform and it is therefore a potential HSR host. The Dent Group is a varied sequence of limestones, sandstones, siltstones, mudrocks and volcanic rocks. Locally, the mudrocks may be sufficiently thick to be a potential HSR.
- The Borrowdale Volcanic Group of the south-east part of the Lake District and the similar Eycott Volcanic Group in the north were produced during explosive volcanic activity 450 to 455 million years ago. The Borrowdale Volcanic Group is around 6,000m thick and the Eycott Volcanic Group is over 3,000m thick. These volcanic rocks comprise a mix of fragmented material thrown into the atmosphere during explosive eruptions (pyroclastic rocks, including tuff) and solidified lava flows that ran across the land surface or built up as domes around individual vents and fissures. Although the varied rock types in these volcanic formations would have had very different properties when first erupted, they have been extensively compacted and metamorphosed and are now more uniform and the tuff deposits have been largely transformed to green slates. The large volumes of rock with relatively uniform properties therefore make these volcanic rocks potential HSR host rocks.

- The Skiddaw Group of Ordovician age (approx. 445 to 485 million years old) is found in both the north and south of this subregion, extending east into the North Pennines. These rocks form a sequence of mudstones and sandstones approximately 5,000m thick. They have been folded and metamorphosed such that the predominant rock type is slate and are therefore potential HSR host rocks.
- Several intrusive igneous rocks in the subregion are potential HSR hosts. There are 2 ages of granite (Devonian, approx. 300 to 360 million years old and Ordovician, approx. 445 to 485 million years old), together referred to as the Lake District Batholith. They occur at the surface in several separate bodies and underlie much of the central Lake District. The Shap and Skiddaw granites are surrounded by haloes of baked and very hard metamorphic rocks in which Skiddaw Group and Borrowdale Volcanic Group rocks were heated by the intrusions and recrystallized. Both the granites and the surrounding metamorphic rocks are potential HSR host rocks. The extent of the granites within the depth range of interest is largely based on geological mapping at the surface and geophysical gravity surveys.

A summary of the geological attributes of the Northern 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

The basement rocks in this subregion are affected by both major faulting and folding (Figure 2). The subregion is cut by a number of large faults oriented roughly north-south, but there are also a number of east-west faults, especially in the north of the subregion. There are also zones of faulting at the western and northern margins. 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 rock layers tend to dip steeply in the north of the subregion, but are broadly flat-lying over the Lake District Batholith. Steep dips occur again around Windermere, but the rocks become gently dipping again further to the south-east. Variable and steeply dipping rocks are likely to complicate the search for a volume of rock with sufficiently uniform properties in these areas.

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 main source of water in much of subregion 3 is surface storage because many of the rocks are of very low permeability, even at surface, and there are few aquifers. Around the margins of the Lake District, Triassic and Permian sandstones are principal aquifers which are used for public water supply, and there are also Carboniferous sandstones which act as local aquifers.

The basement rocks do not normally provide a water source except where intensely fractured and weathered near the surface and there is little or no information about the hydrogeological properties of potential host rocks at depth, except for the small area around Sellafield in west Cumbria, at the margin of the subregion, which was investigated previously (see also subregion 4). There are no clay-rich rock layers overlying the basement rocks in this subregion to provide hydraulic separation between deep and shallow groundwater. Mineral springs are known near Shap, 16km south of Penrith, and Keswick, suggesting discharge of groundwater that has moved through cracks lined with calcite, but there are no natural thermal springs to suggest rapid flow of deep groundwater to the surface.

Mining in some parts of the subregion is likely to have changed the original patterns of water movement and shallow groundwater may now circulate to greater depths within the range of interest than it did before mining. In the vicinity of the coal and iron mining areas around Whitehaven, Egremont and Barrow-in-Furness deep exploration boreholes may influence the connectivity between shallow and deep groundwater which would also need to be considered during the siting process (Figure 3).

[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.

Resources

Extensive iron mining below 100m has taken place along the north-western and south western margins of the subregion and there are also mines extending to depths greater than 100m around Coniston (copper) and at Glenridding by Ullswater (copper and lead) (Figure 4a). The West Cumbrian Coalfield lies in the westernmost part of the subregion (Figure 4b). 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. These known resources would be taken into account in the siting of a GDF.

A Petroleum Exploration and Development Licence is currently held for part of the subregion around Barrow-in-Furness (Figure 4c). There are also Coal Authority Licence Areas in the inshore part of this subregion off the coast of Whitehaven (Figure 4b). It is not known whether coal, oil or gas in these licence areas will be exploited, but they would need to be considered during the siting process.

Anhydrite and gypsum were mined below 100m in the vicinity of Whitehaven although both mines are now closed (Figure 4d). Although the nature of mining in evaporites does not affect the movement of groundwater in the surrounding rocks in the same way as other mining, the presence of any excavations in these rocks would need to be considered in the siting of a GDF.

Areas of historical metal ore mining are also shown in Figure 4d but are not relevant to the siting of a GDF as the mines are shallower than 100m.

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 1 The areas of the Northern England subregion 3 where Higher Strength rock types of interest are present between 200 and 1,000 m below NGS datum.

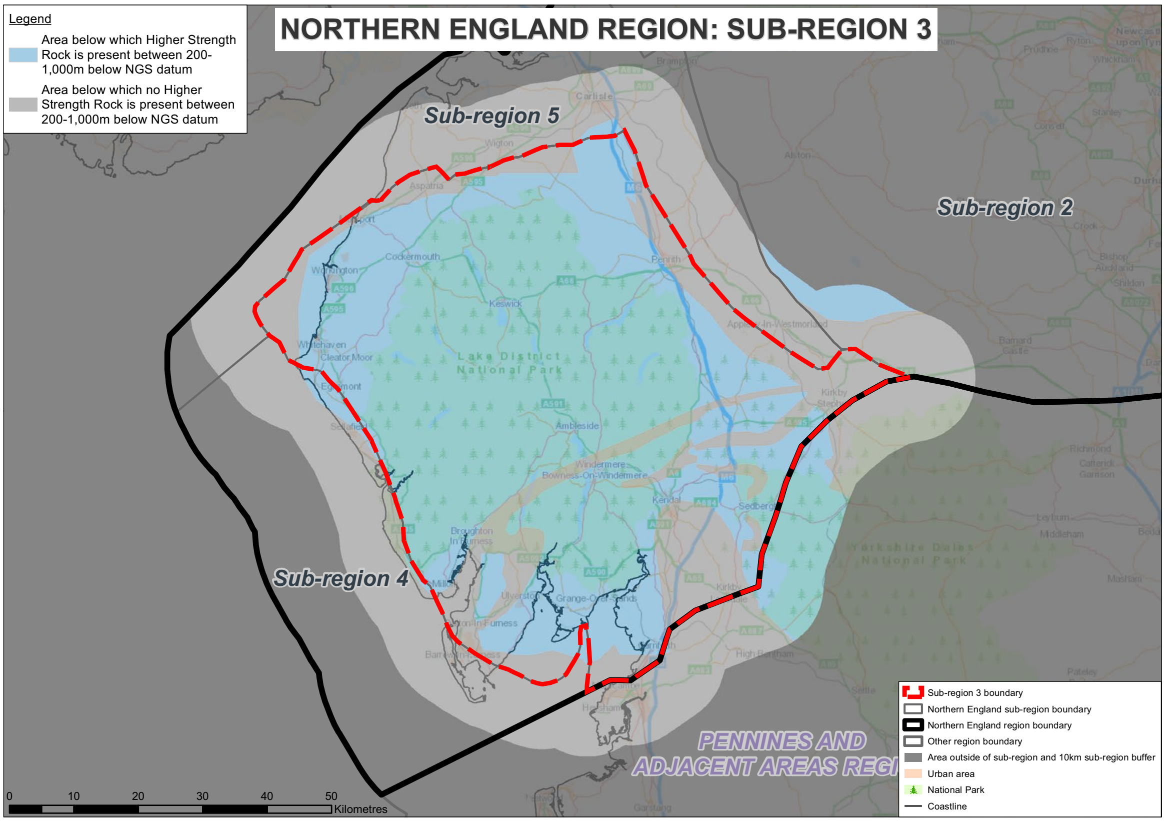


Figure 2 Major faulting and folding in the Northern England subregion 3.

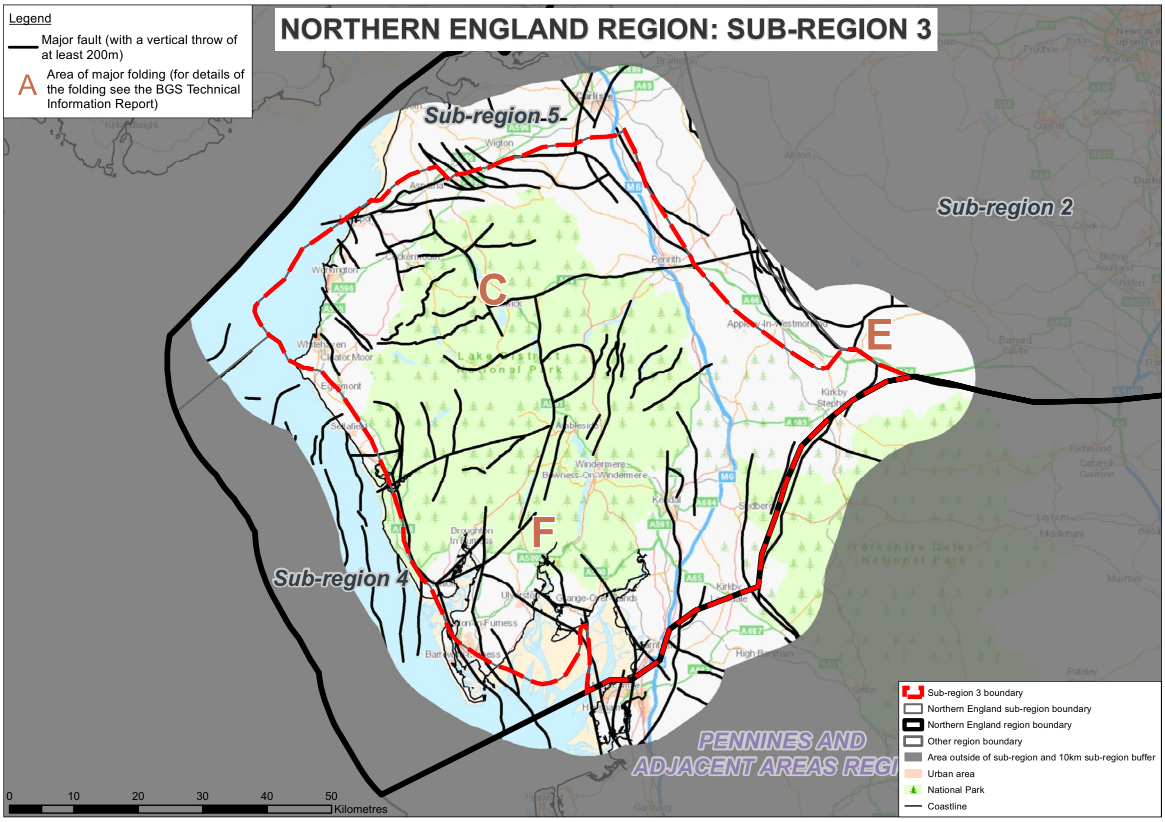


Figure 3 Areas in the Northern England subregion 3 with concentrations of deep exploration boreholes.

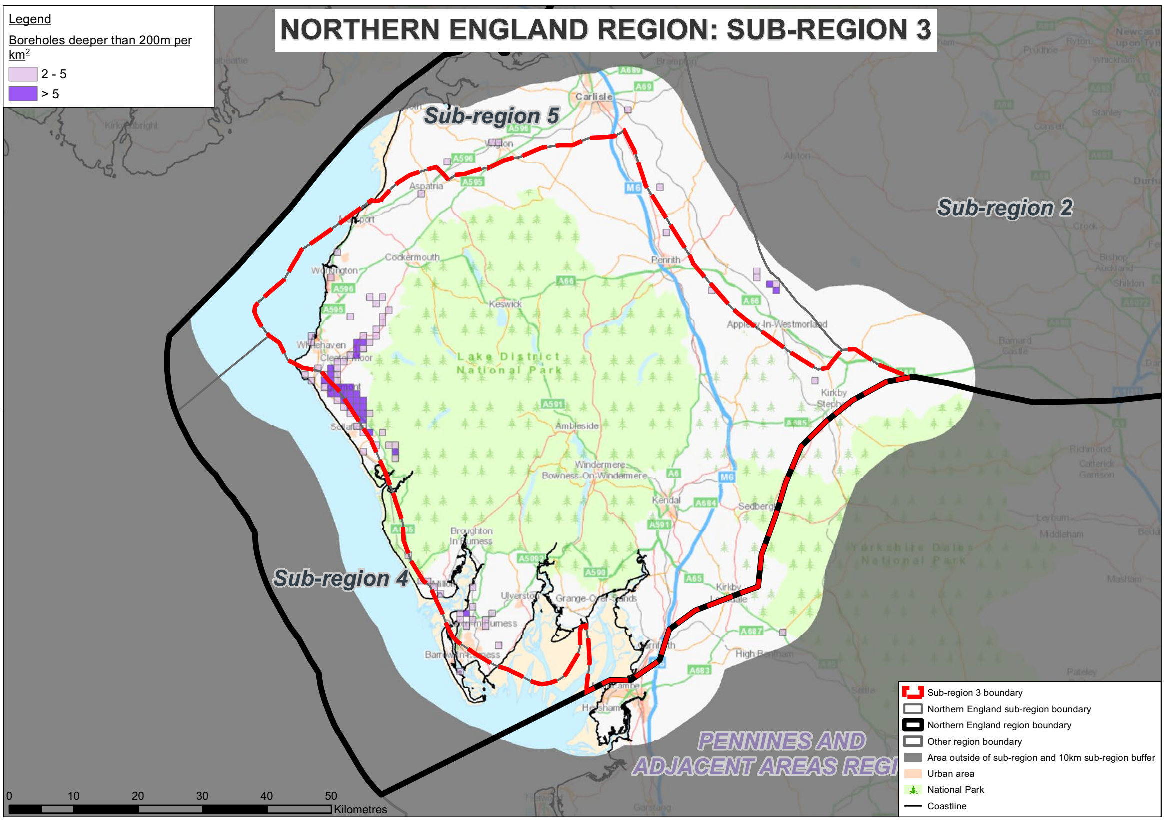


Figure 4a Areas of the Northern England subregion 3 with iron, copper and lead mines present below 100m.

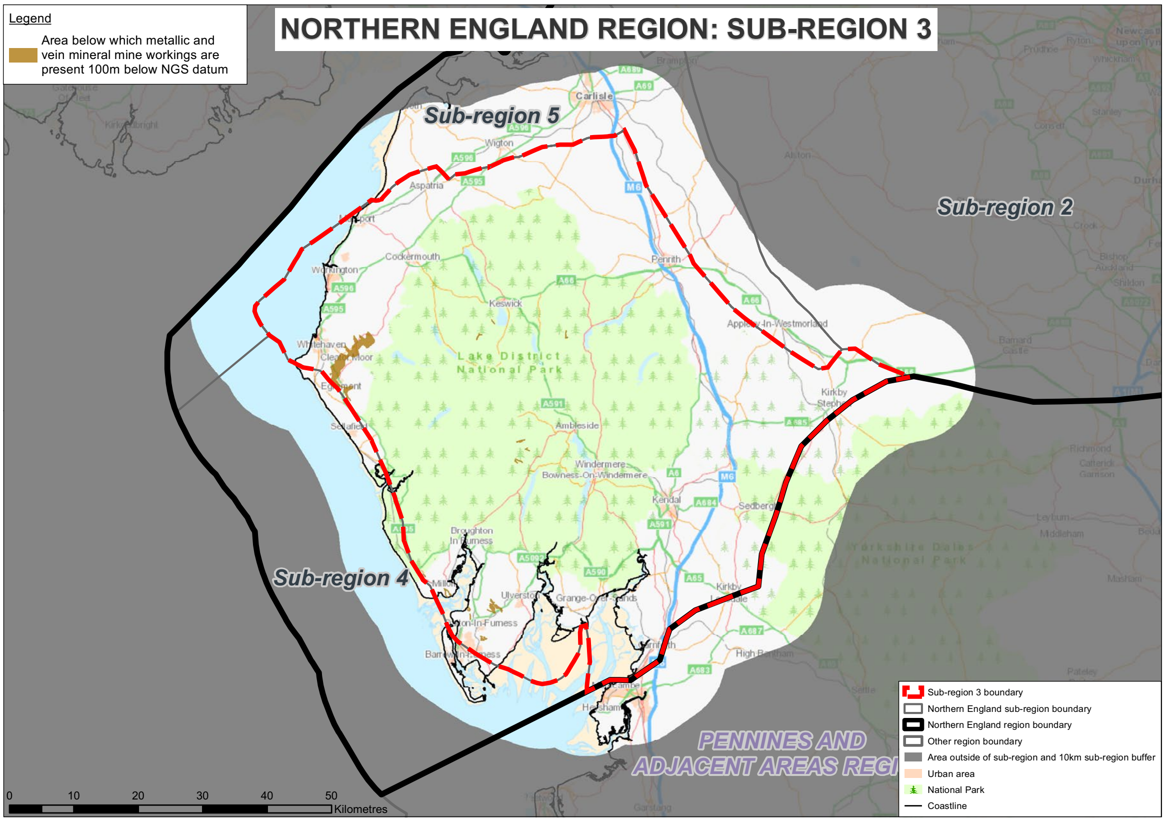


Figure 4b Areas of the Northern England subregion 3 with coal mines more than 100m deep and Coal Authority Licence Areas.

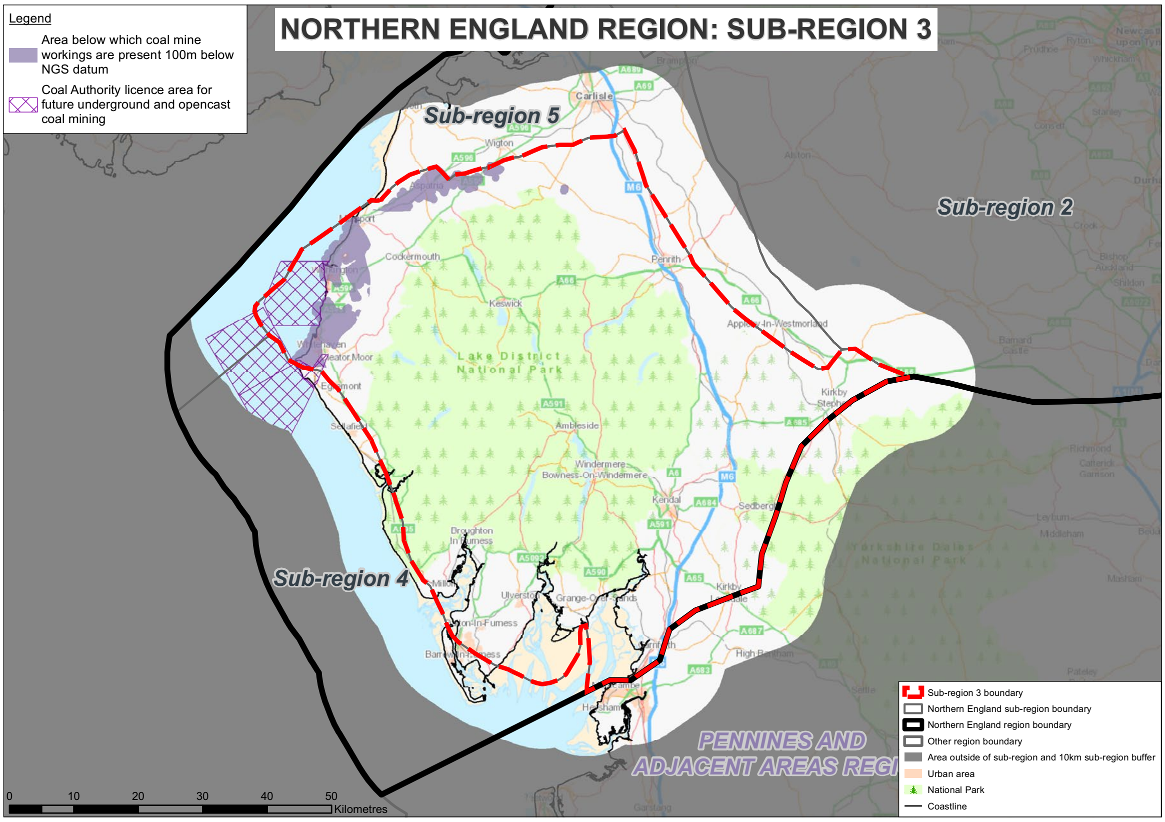


Figure 4c Areas of the Northern England subregion 3 with Petroleum Exploration and Development Licences.

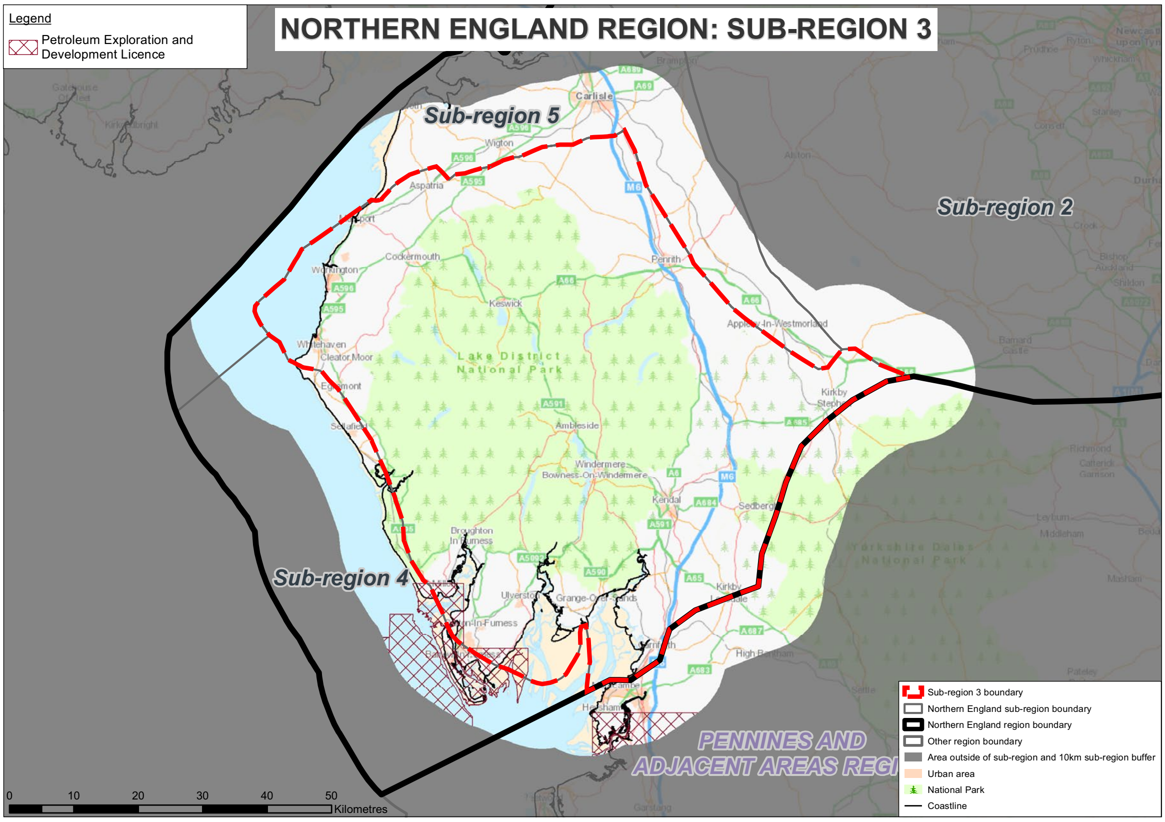
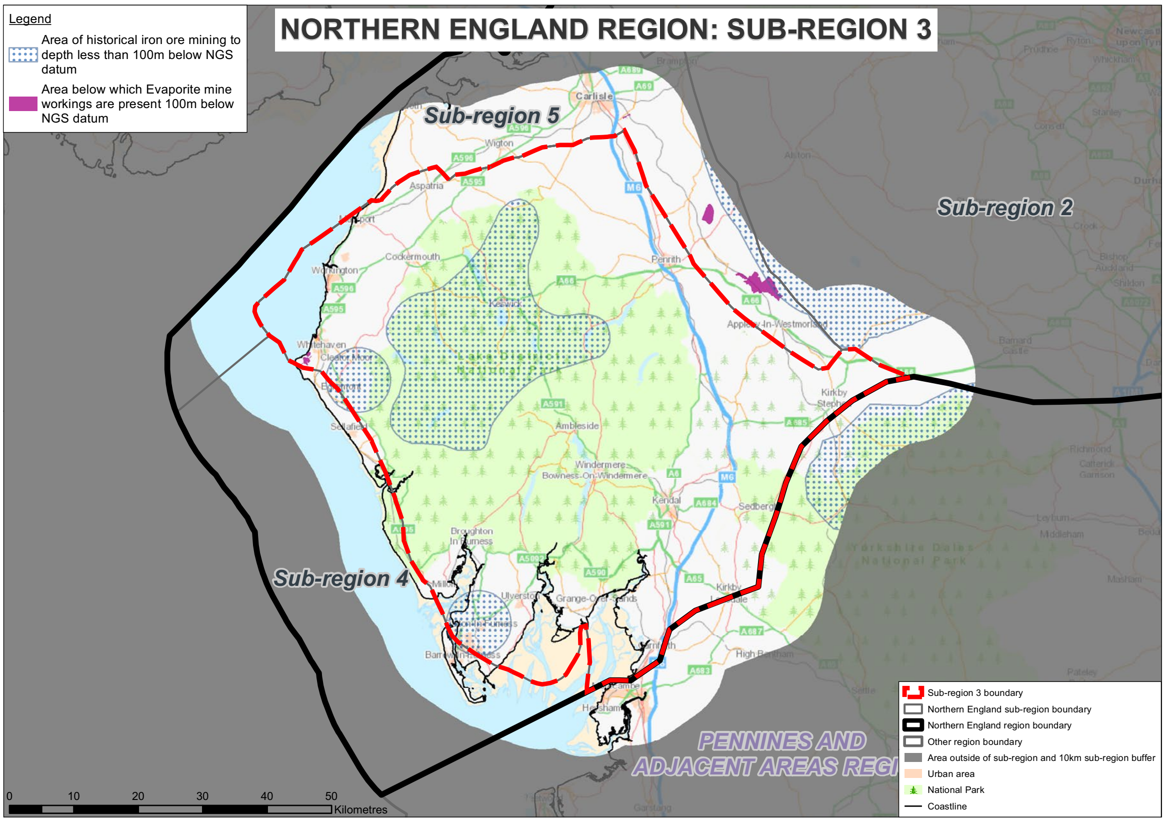


Figure 4d Areas of the Northern England subregion 3 with historical iron ore mines less than 100m deep and historical evaporite mines below 100m.



Glossary

Anhydrite
A calcium sulphate mineral that forms from the evaporation of salty seas. It contains no water and occurs at greater depths and higher temperatures than gypsum.

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.

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

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.

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.

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.

Intrusive igneous rock
The process by which magma is forced along cracks and fissures in the earth's crust, subsequently cooling to form igneous dykes and batholiths.

Lava flow
A mass of flowing or solidified lava. After cooling and solidification, lava flows often form distinctive topographical features.

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

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.

Pyroclastic
Deposits of solid material erupted explosively from a volcano, ranging in size from large blocks and boulders to very fine ash. The citizens of Pompeii were buried beneath thick clouds of hot pyroclastic material in 79AD.

Glossary

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.

Slaty

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

Tuff

Fine-grained rock formed from compacted ash ejected during explosive volcanic eruptions.

Radioactive Waste Management

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