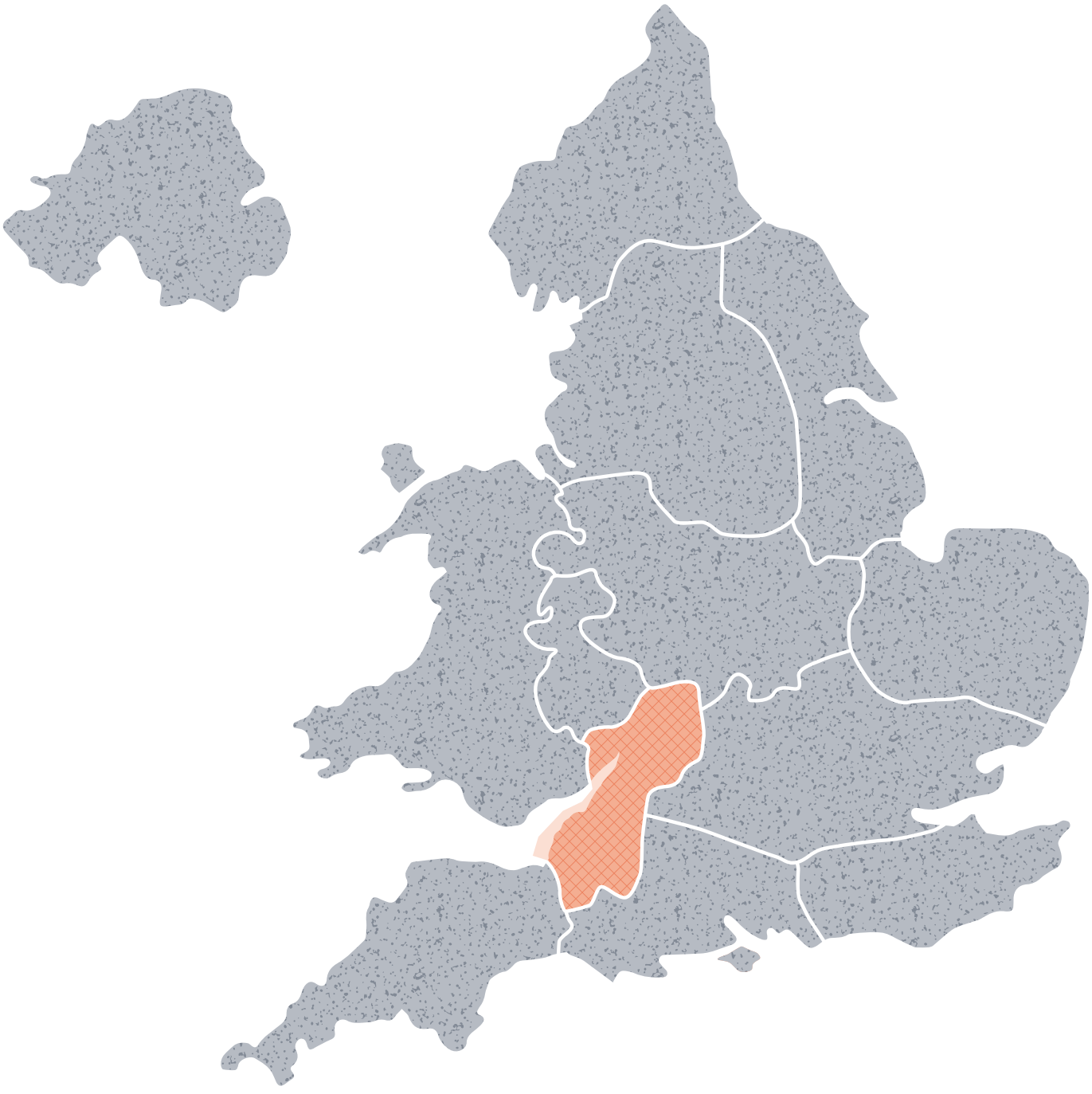
Radioactive Waste Management



Bristol and Gloucester

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 Gloucestershire and north and central Somerset. It includes the Severn Estuary and the inshore area of the Bristol Channel with the north-west boundary of the region being the Welsh border.

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.

Bristol and Gloucester: 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. There are a number of shallower boreholes, which 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.

Available information for this region

There are concentrations of boreholes extending below 200m associated with the Bristol and Somerset and Forest of Dean coalfields, but only 6 boreholes in the region extend below 600m. This information is supplemented by geophysical investigations including studies of the Earth's gravity and magnetic fields, and a network of exploration seismic survey lines in the west and east of the region. 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 3 main groups: younger sedimentary rocks, older sedimentary rocks and basement rocks. These are summarised in Figure 2 which shows the oldest and deepest rocks at the base 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. Figure 4 presents a schematic vertical cross section 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 5a to 5d 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 youngest rocks occurring in the depth range of interest are sedimentary rocks of Jurassic, Triassic and Permian age (approx. 145 to 300 million years old) which are referred to here as the younger sedimentary rocks. The Jurassic rocks are mainly mudstones and limestones while the Permian-Triassic rocks are predominantly reddish-brown mudstones, sandstones and siltstones with local evaporites. The evaporite sequences consist of mudstones interlayered with dolomite, gypsum, anhydrite and rock salt (halite). There are several units in the younger sedimentary rock sequence that contain thick mudstones and are likely to behave as LSSR.

Older sedimentary rocks

The region also contains older sedimentary rocks dating from the Carboniferous and Devonian periods (approx. 300 to 420 million years old) (Figure 2):

- Uppermost Carboniferous Warwickshire Group rocks, which in this region includes a number of coal seams that have been mined in the past
- South Wales Coal Measures Group dominated by coal, mudstone and sandstone
- Upper Carboniferous sandstone-dominated rocks (Marros Group)
- Carboniferous Limestone Supergroup, known from the Mendips in particular
- Devonian Old Red Sandstone comprising reddish-brown sandstones, siltstones and mudstones which mainly occur at the surface west of the Severn Valley
- Middle and Lower Devonian sandstones and siltstones

These rocks comprise the older sedimentary rocks and provide the cover to the basement rocks beneath them.

Basement rocks

The oldest rocks of the region are Silurian shales, sandstones and volcanic rocks (approx. 420 to 485 million years old) which form the basement to the sedimentary rocks that rest on top of them. The Silurian volcanic rocks may have potential as HSR host rocks and are exposed at the surface in the Mendips.

Rock structure

There are a number of major faults and areas of major folding in the region (Figure 6). Throughout this region basement rocks and their older sedimentary cover are more intensely folded and faulted than the younger sedimentary cover (Figure 6). A distinctive belt of deformation extending across south-west Britain is composed of steep-sided folds with major faults at their centres. It is typified by the Mendip Hills in the southern part of this region, and is made up of prominent domes of Carboniferous Limestone Supergroup often cut through by glacial outwash valleys dating from the last Ice Age, such as Cheddar Gorge. Toward Bristol and Gloucester, younger sedimentary rocks laid down after the deformation had ceased cover the folds which become progressively more deeply buried beneath the younger sedimentary rocks further north. In the south-west, older sedimentary and basement rocks, cut by major faults and folds, extend through much of the depth range of interest.

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. The region contains several principal aquifers including the Sherwood Sandstone Group, Great and Inferior Oolite Groups and Bridport Sand and Blue Lias Formations in the Lias Group which are used for public water supply. In the east of the area from the Cotswolds south to Wincanton, the dominant aquifers are limestones (including Chalk in the far south-east). 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. Groundwater from depths greater than 400m is unlikely to be suitable as drinking water anywhere in the UK [1] .

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

In the centre of the region, from the Forest of Dean to the Mendips, groundwater flow is dominated by the Carboniferous Limestone aquifer. The Carboniferous Limestone aquifer exhibits karstic features, such as in Cheddar Gorge, where concentrated flow of mildly acidic groundwater has enlarged fractures by dissolution to form a network of major fissures and caves, resulting in fast movement of groundwater near the surface. There are natural thermal springs at Bath and Bristol providing evidence for local deep circulation of groundwater through limestone and rapid flow back to the surface (Figure 7a).

Where mining has occurred it is likely to have changed the original patterns of water movement and shallow groundwater may circulate to greater depths within the range of interest now than it did before mining.

Resources

Iron ore was mined in the Forest of Dean, with a few mines extending below 100m in the east (Figure 7a). Coal has been mined at depths greater than 100m in the past on either side of the Severn Estuary, in the Forest of Dean and Bristol and Somerset Coalfields and there are Coal Authority Licence Areas in the Forest of Dean (Figure 7b). There are Petroleum Exploration and Development Licences for a largely onshore area around Weston-super-Mare (Figure 7c).

The Mendips have been a source of lead and zinc from Roman times up to the early 20th century, but none of the mines are known to have penetrated below 100m (Figure 7d).

Rock salt has been extracted by solution mining from the Somerset Saltfield in the south-west of the region, but much of the salt is at a depth of around 700m and has not been exploited.

The areas where concentrations of deep exploration boreholes would need to be considered in the siting of a GDF are also shown in Figure 8.

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 other parts of England and Wales. There are no particular locations where they are more frequent. No earthquakes with magnitude of 4.0Mw or greater have been recorded in the region, either by modern instruments or in historic records.

Whilst the design of a GDF will need to consider the potential impact of earthquakes, there is no evidence that future seismicity anywhere in the UK would preclude its development.

The extreme north and west of the region was affected by the Anglian continental-scale glaciation during the Pleistocene epoch, but it has otherwise been beyond the limits of ice sheets. Permafrost is likely to have been extensive during continental-scale glaciations and would have influenced groundwater behaviour. It is impossible to predict the timing and likely extent of ice in the next ice age, due in some tens to hundreds of thousands of years' time, but in this southern part of the country glaciation is likely to be infrequent. 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 locally increased erosion and changes to the pattern of groundwater movement.

The low-lying 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

More information about the geology of the region can be found in the BGS Regional Summary, with additional detail in the BGS Regional Guide. Note that the BGS Bristol and Gloucester region extends into adjacent parts of Wales; these have been treated as part of the Wales region for National Geological Screening. The BGS Regional Guide also provides details about many of the sources of information underpinning the TIR.

Figure 1 Subregions of the Bristol and Gloucester region as defined for the purpose of National Geological Screening.

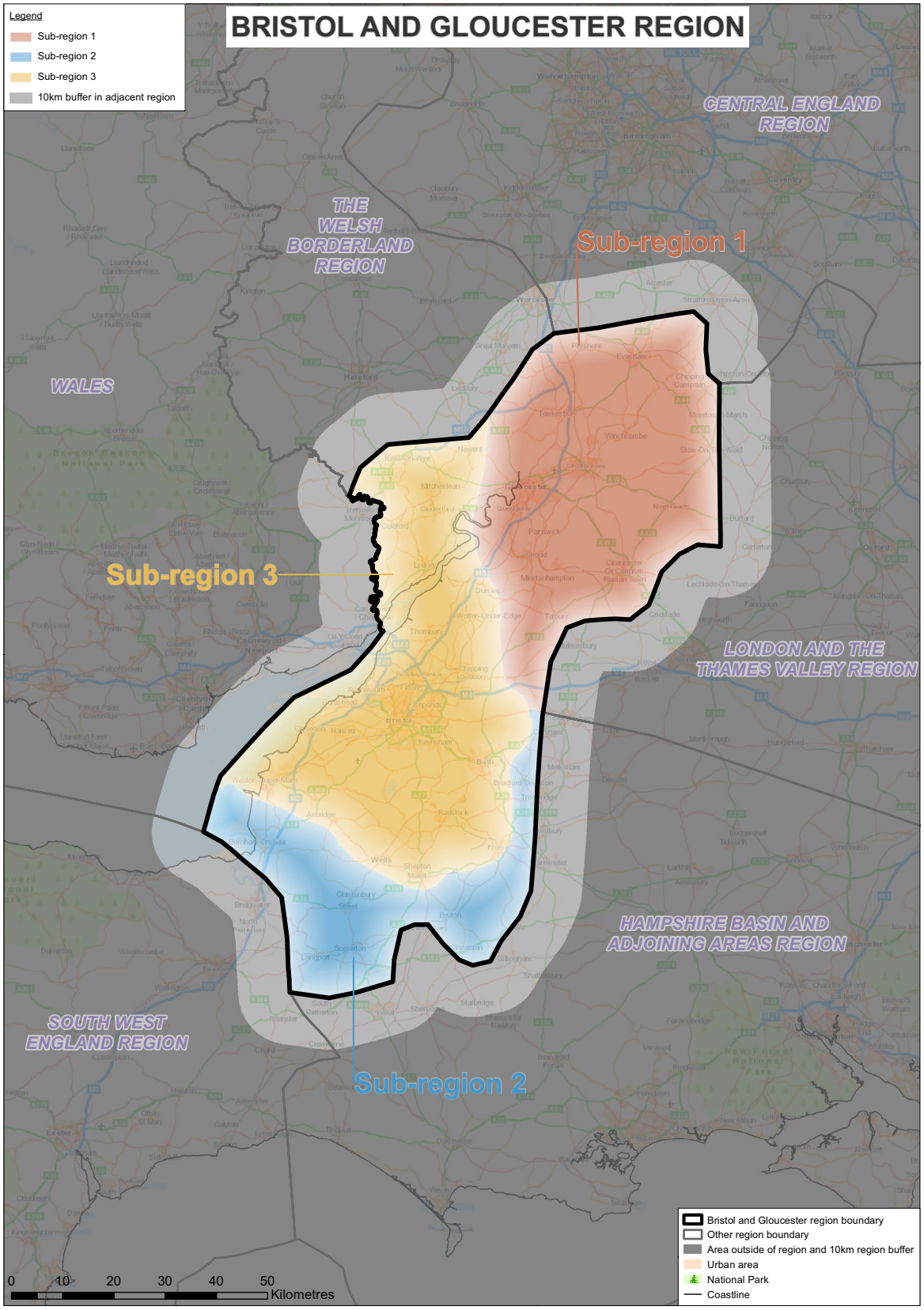
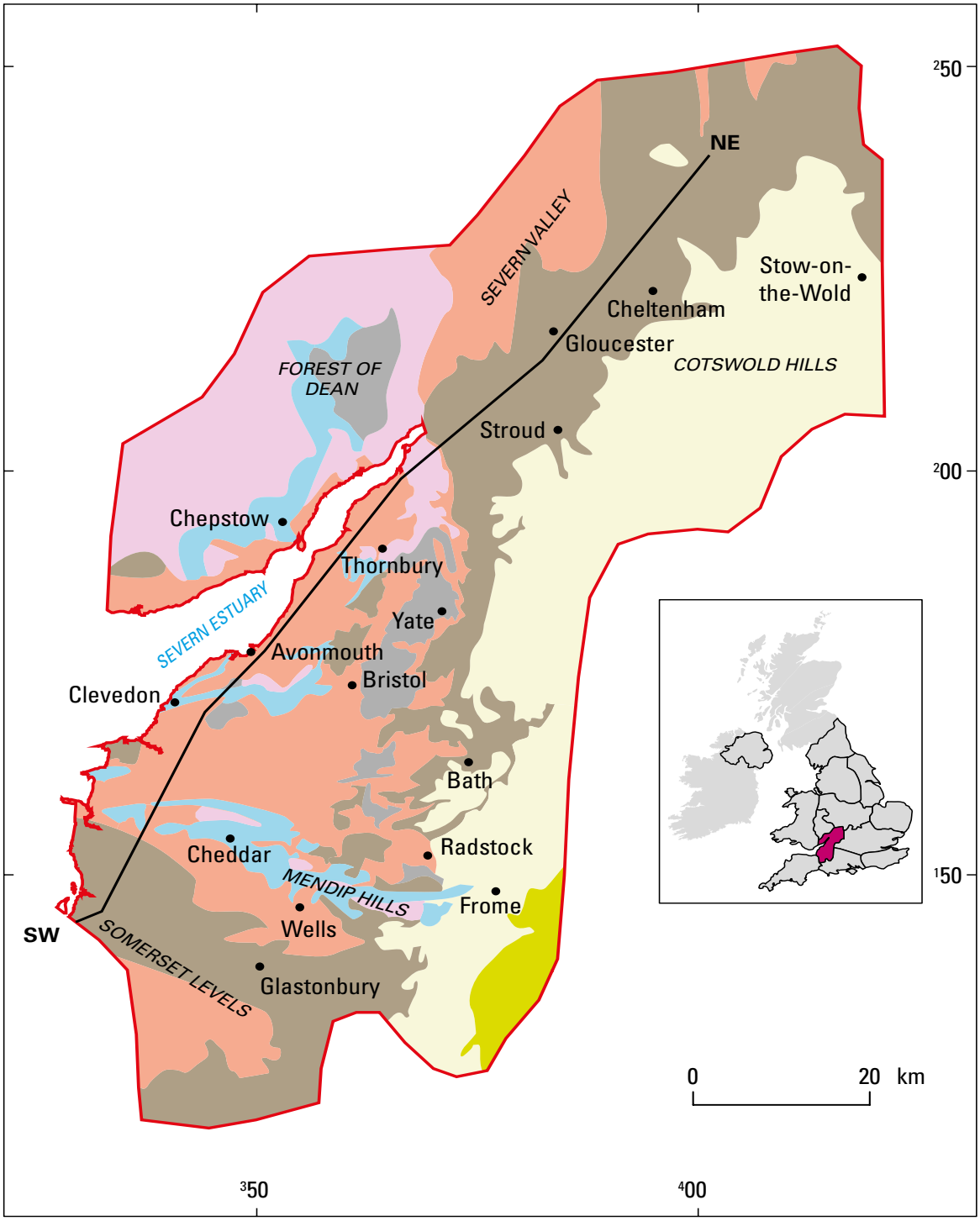


Figure 2 Table illustrating the sequence of the major rock units present in the Bristol and Gloucester region and their possible significance for the siting of a GDF.

	Geological Period (age in millions of years)	Geological Unit	Dominant Lithology	Rock types of interest		
				LSSR	HSR	Evaporite
Younger Sedimentary Rocks	Cretaceous (66.0 – 145.0)	Chalk and Selborne Groups	Not applicable as not within depth range of interest	Not applicable as not within depth range of interest		
	Jurassic (145.0 – 201.3)	Kellaways and Oxford Clay Formations	mudstone and sandstone	✓		
		Corallian Group	limestone, sandstone, siltstone and mudstone			
		Great Oolite Group (inc Frome Clay Formation)	mudstone and limestone	✓		
		Inferior Oolite Group	limestone, sandstone, siltstone and mudstone			
		Lias Group	mudstone, sandstone and limestone	✓		
	Triassic (201.3 – 251.9)	Penarth Group	mudstone, limestone and sandstone	✓		
		Mercia Mudstone Group	mudstone with siltstone, sandstone and evaporites	✓		✓
		Sherwood Sandstone Group	sandstone with conglomerate and mudstone			
	Permian (251.9 – 298.9)	Undifferentiated (inc Bridgnorth Sandstone)	sandstone and conglomerate			
Older sedimentary and related	Carboniferous (298.9 – 358.9)	Warwickshire Group	sandstone and mudstone	✓		
		South Wales Coal Measures Group	mudstone, siltstone, sandstone and coal			
		Marros Group	sandstone, siltstone and mudstone			
		Carboniferous Limestone Supergroup	limestone and sandstone			
	Devonian (358.9 – 419.2)	Upper and Lower Old Red Sandstone Groups	sandstone, conglomerate, siltstone and mudstone			
		Middle and Lower Devonian rocks undifferentiated	mudstone, siltstone and sandstone		✓	
Basement	Devonian to Silurian (358.9 – 443.8)	Volcanic Rocks	weakly metamorphosed basalt and andesite		✓	
	Silurian to Cambrian (419.2 – 541.0)	Undifferentiated	mudstone, sandstone and limestone			

Figure 3 Generalised geological map showing the distribution of rock units in the Bristol and Gloucester region. The inset shows the extent of the region in the UK. The bold black line gives the location of the cross-section shown in Figure 4. See Figure 2 for the key to the rock types.



It should be noted that the area covered by this map is slightly different to the area considered in this document. This is because, unlike the region considered in this study, it refers to the BGS Regional Guide area which does not strictly follow the national boundary of Wales.

Figure 4 Schematic cross-section of the Bristol and Gloucester region along the line 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.

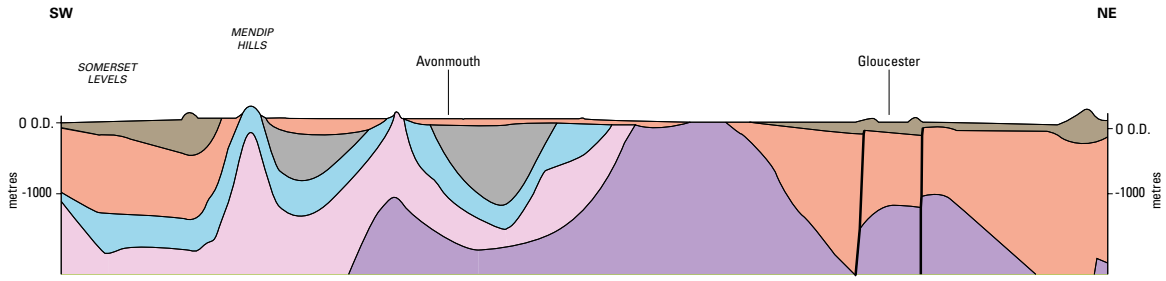


Figure 5a The areas of the Bristol and Gloucester region where any of the 3 Rock Types of Interest are present between 200 and 1,000m below NGS datum.

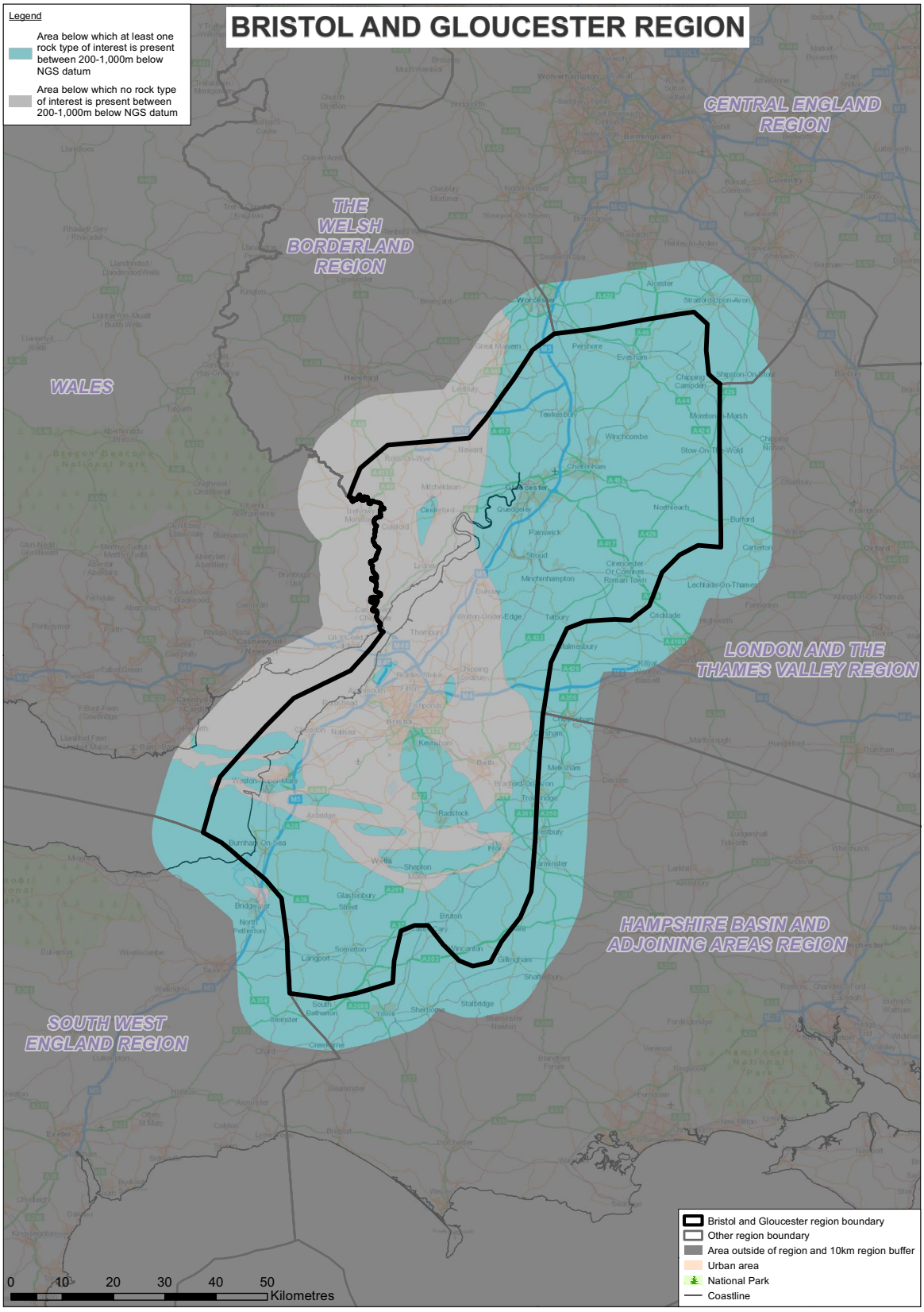


Figure 5b The areas of the Bristol and Gloucester region where Lower Strength Sedimentary Rock Types of Interest are present between 200 and 1,000 m below NGS datum.

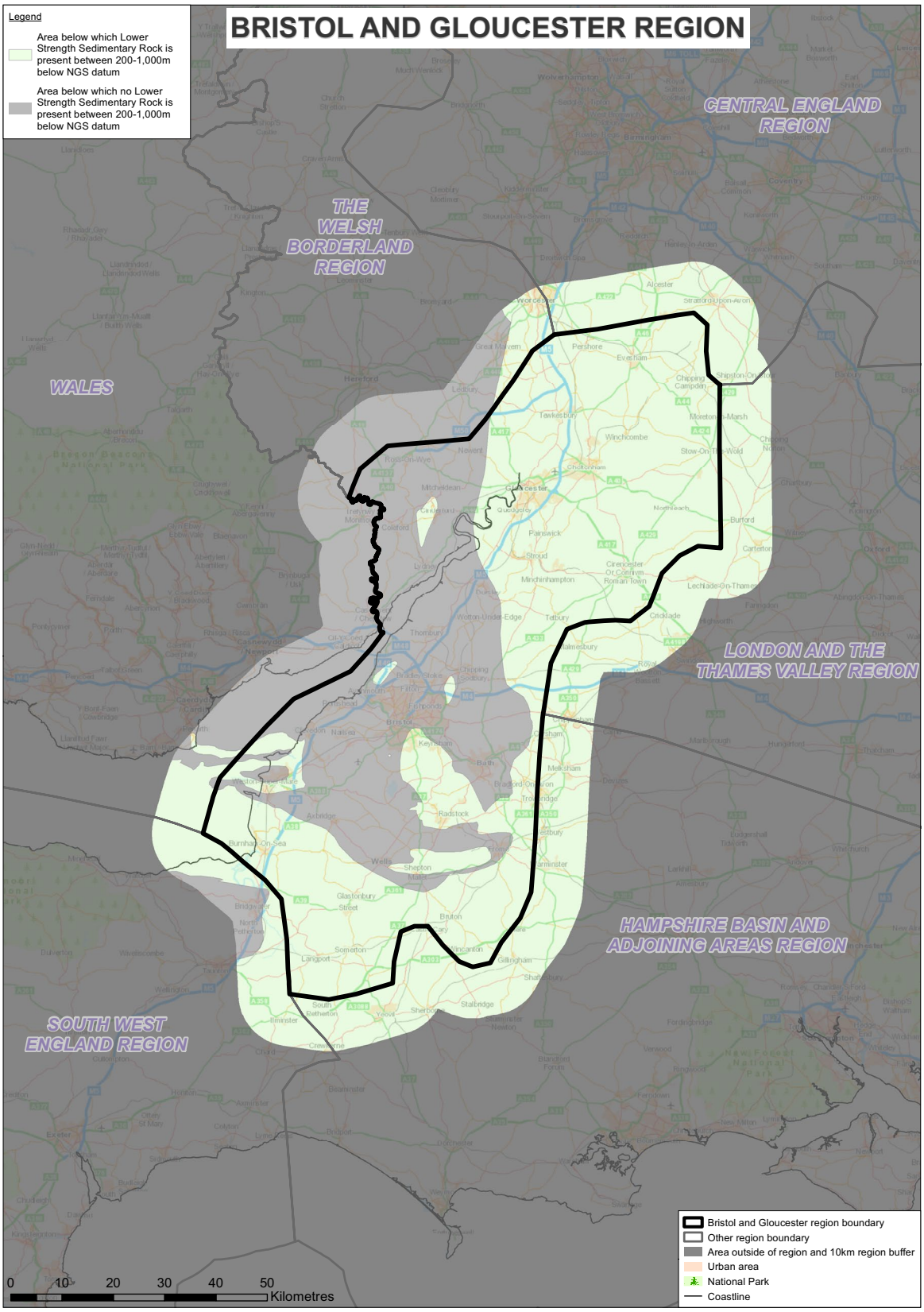


Figure 5c The areas of the Bristol and Gloucester region where Higher Strength Rock Types of Interest are present between 200 and 1,000 m below NGS datum.

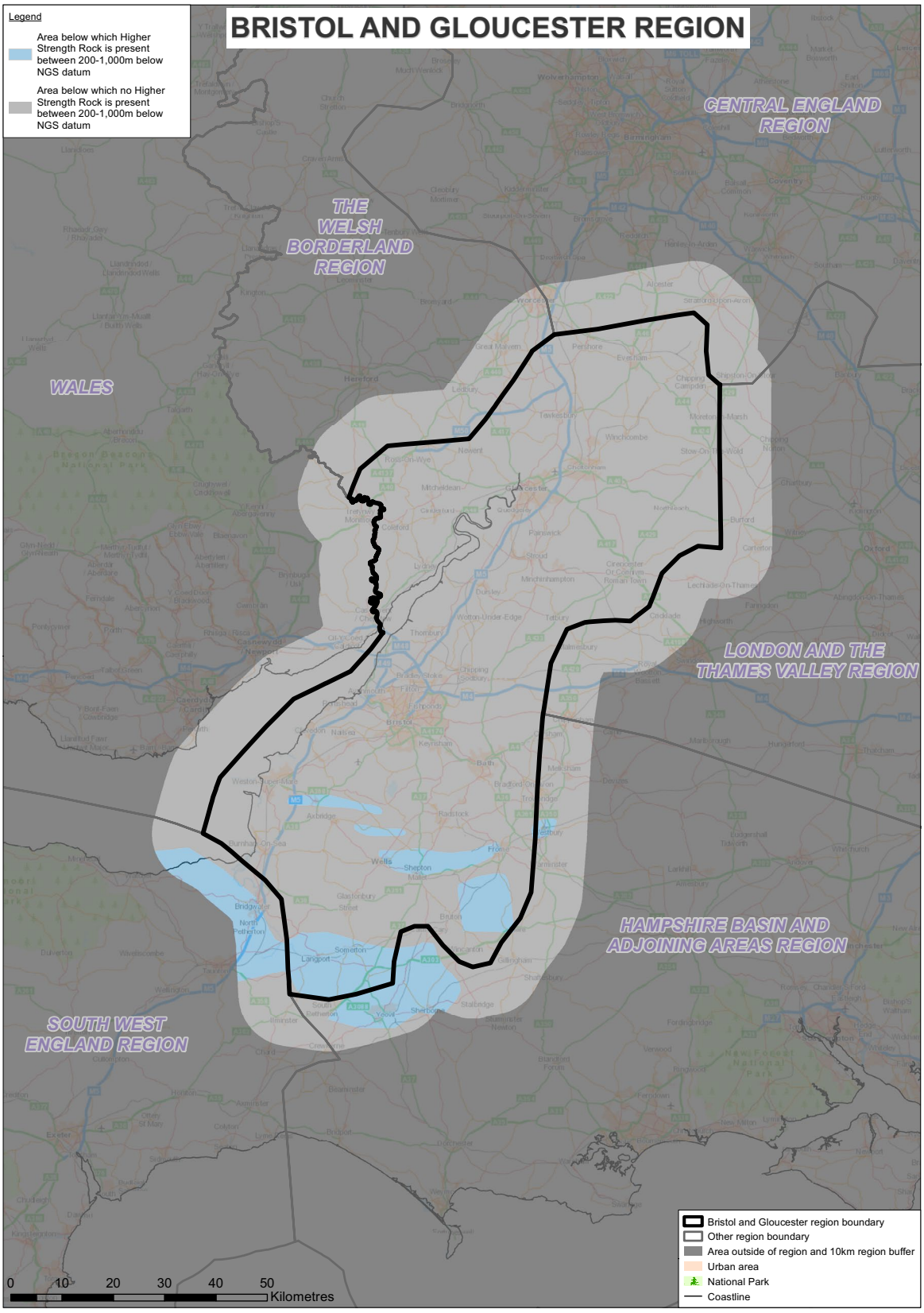


Figure 5d The areas of the Bristol and Gloucester region where Evaporite Rock Types of Interest are present between 200 and 1,000 m below NGS datum.

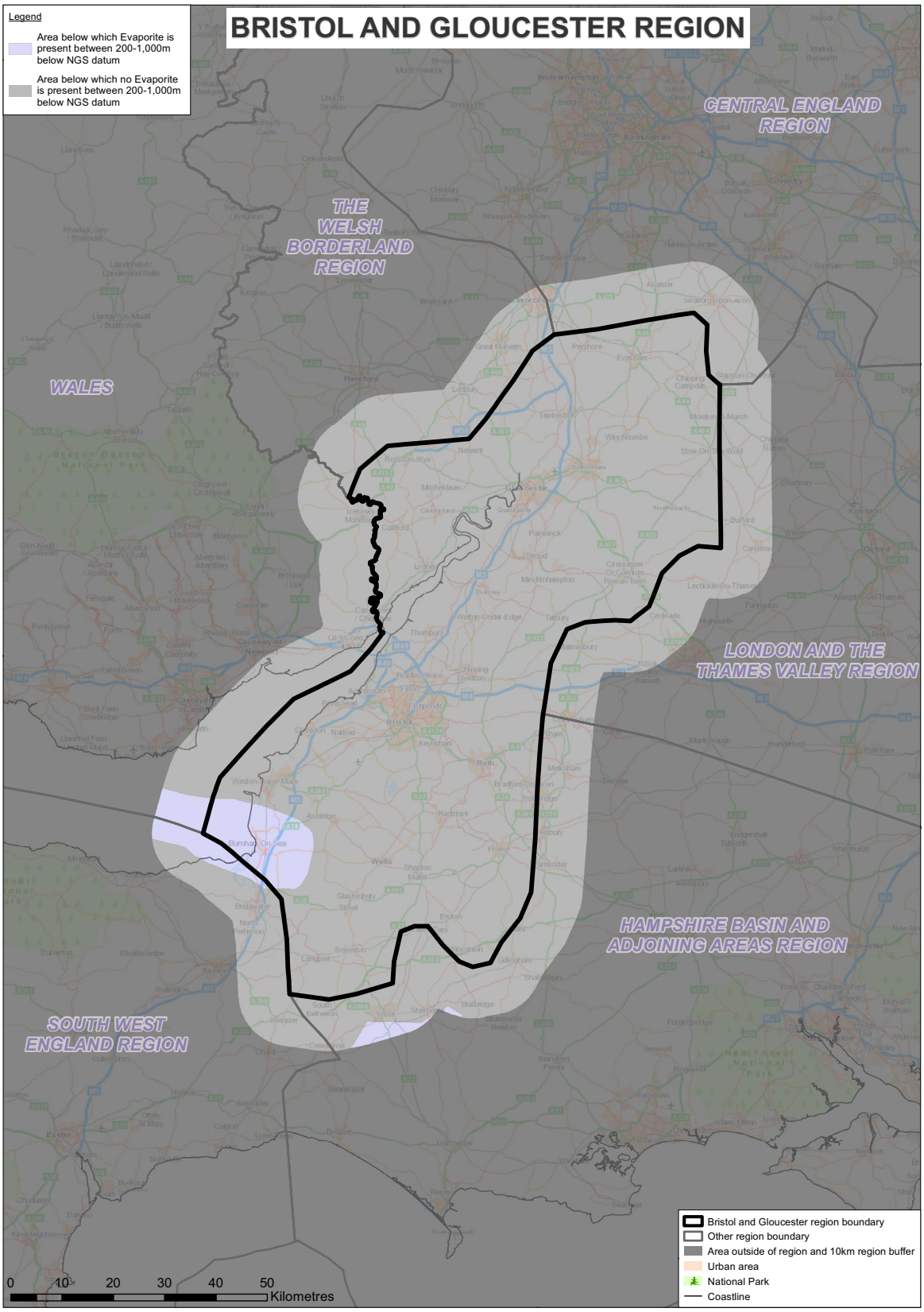


Figure 6 Location of major faults and folding in the Bristol and Gloucester region.

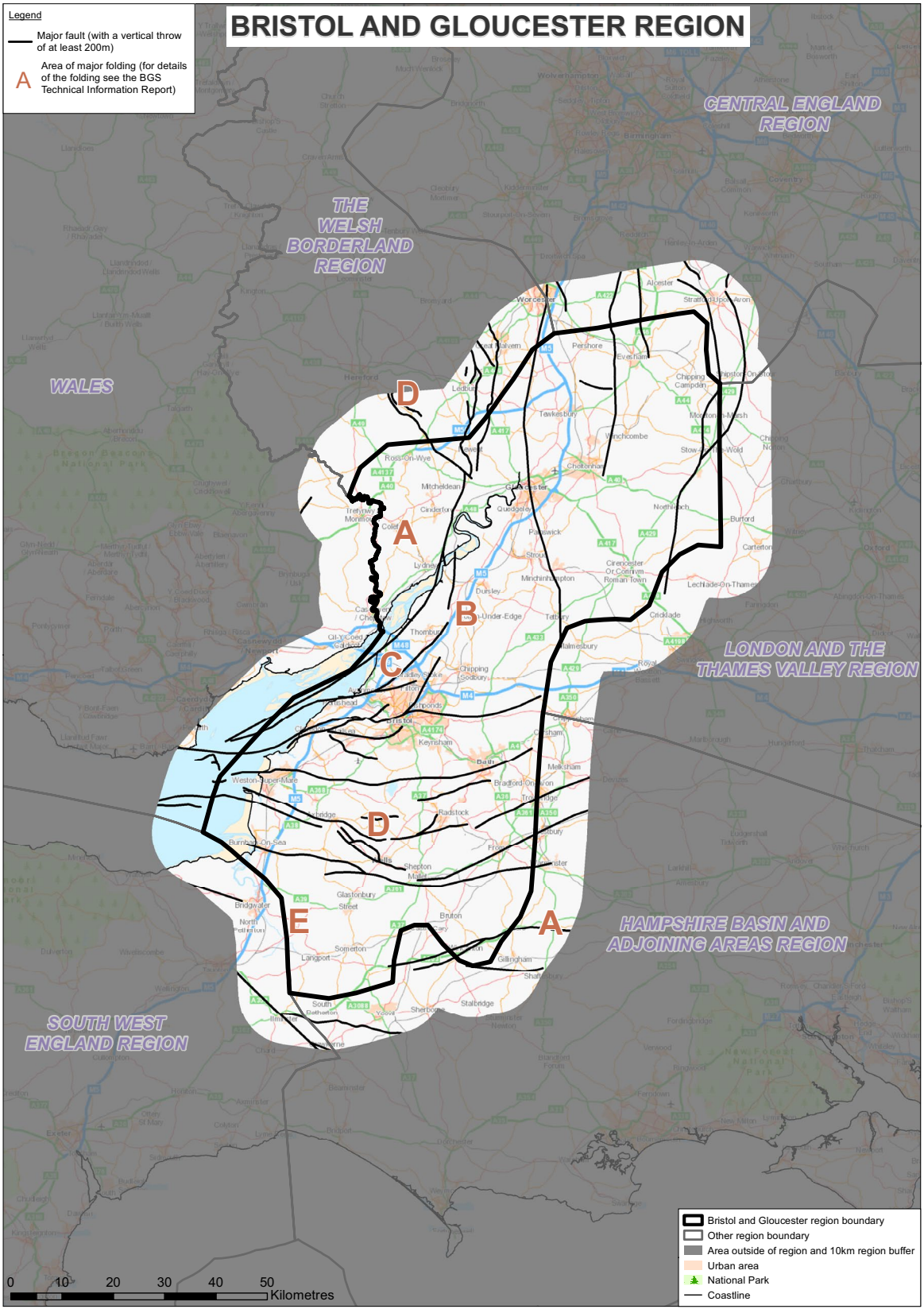


Figure 7a Areas of the Bristol and Gloucester region with thermal springs and iron ore mines present below 100m.

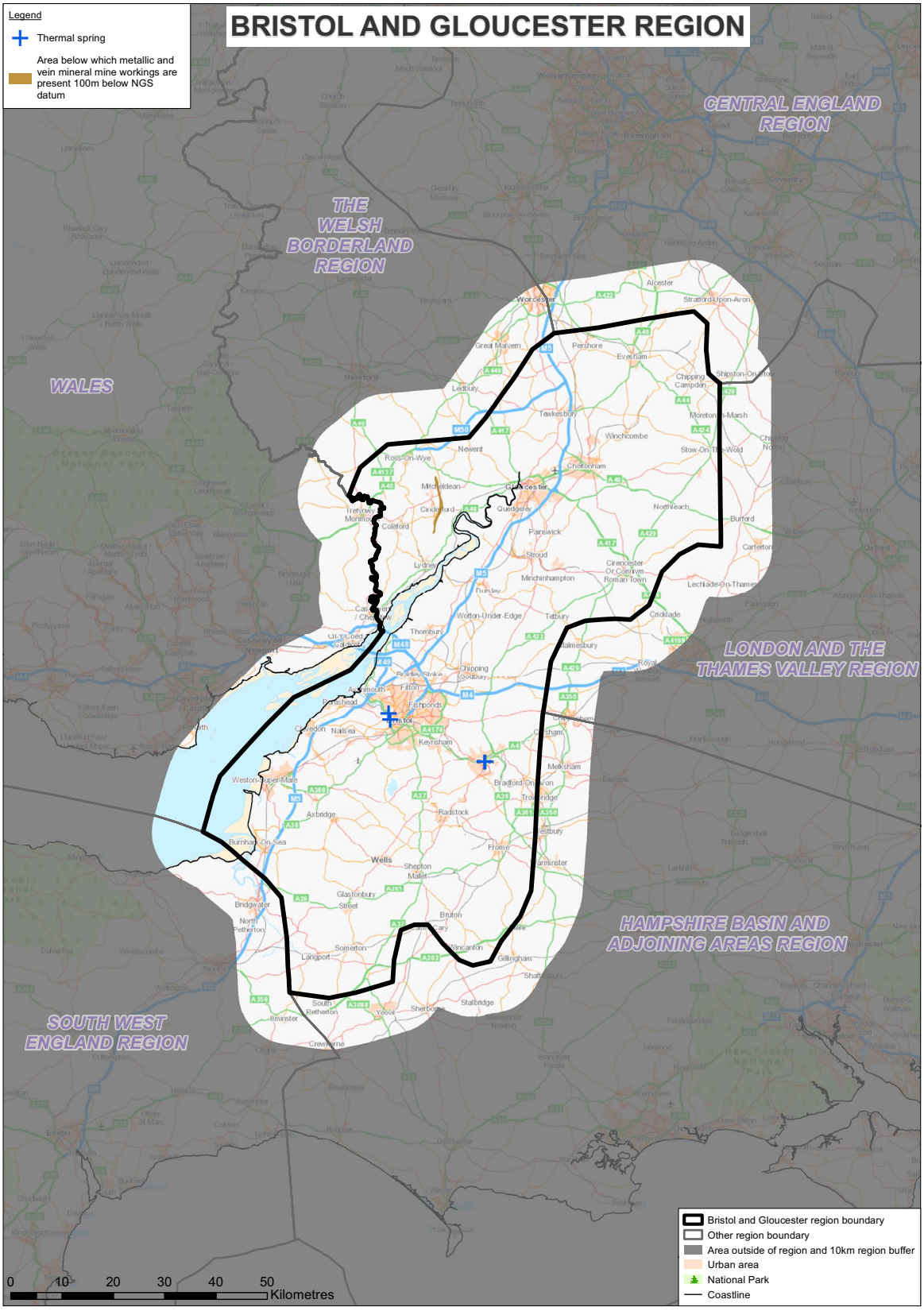


Figure 7b Areas of the Bristol and Gloucester region with coal mines more than 100m deep and Coal Authority Licence Areas.

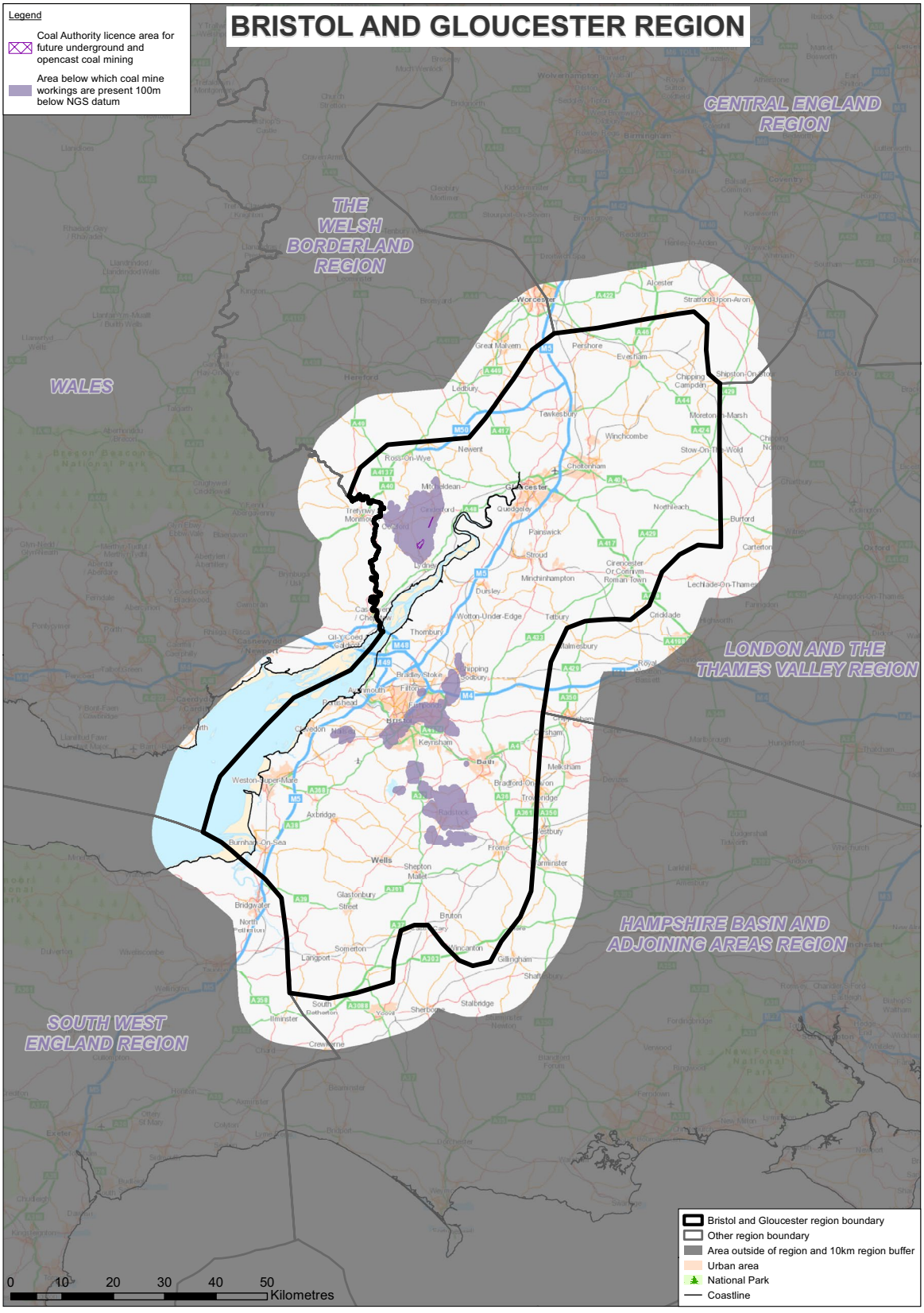


Figure 7c Areas of the Bristol and Gloucester region with Petroleum Exploration and Development Licences.

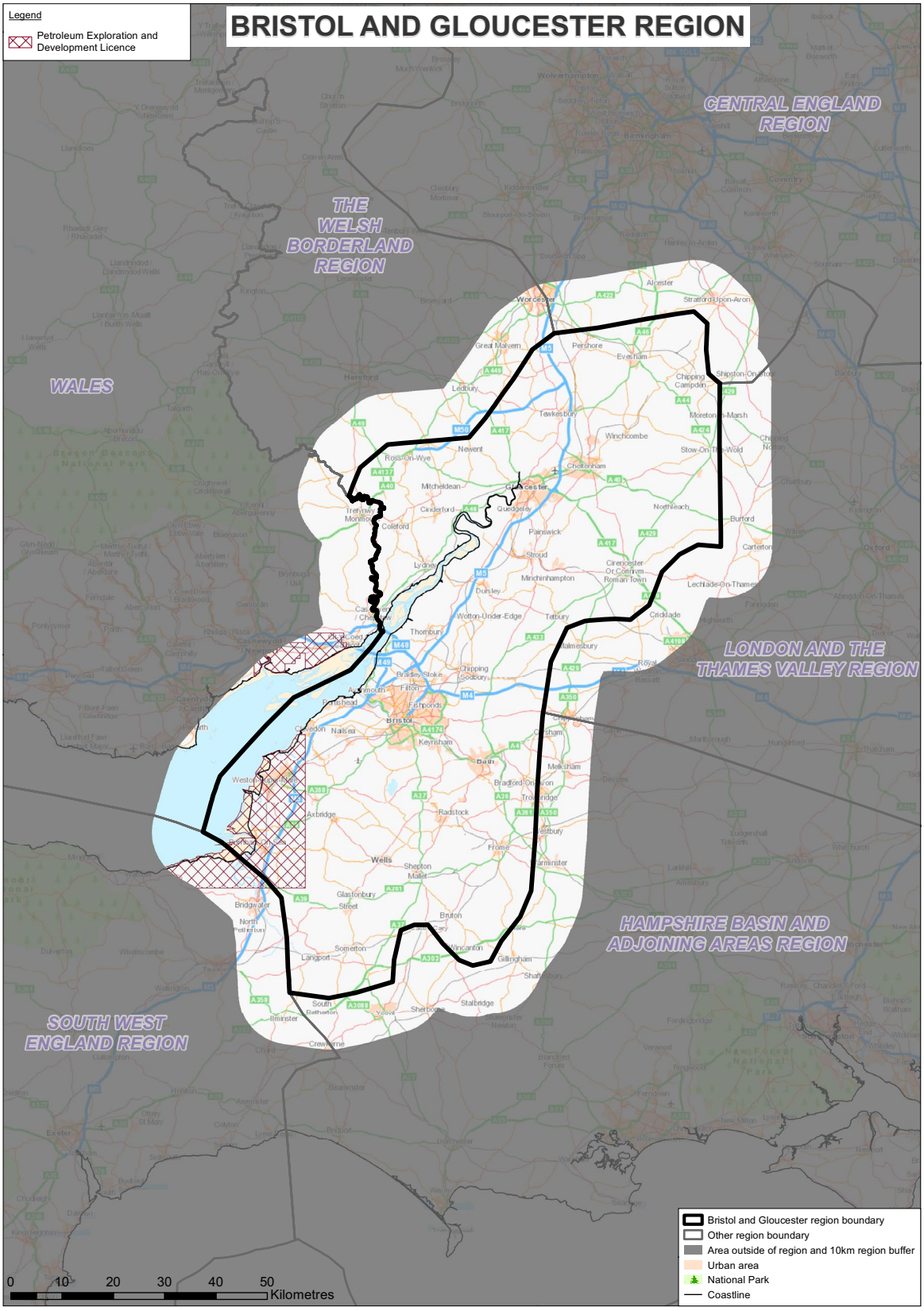


Figure 7d Area of historical lead and zinc mining less than 100m below NGS datum.

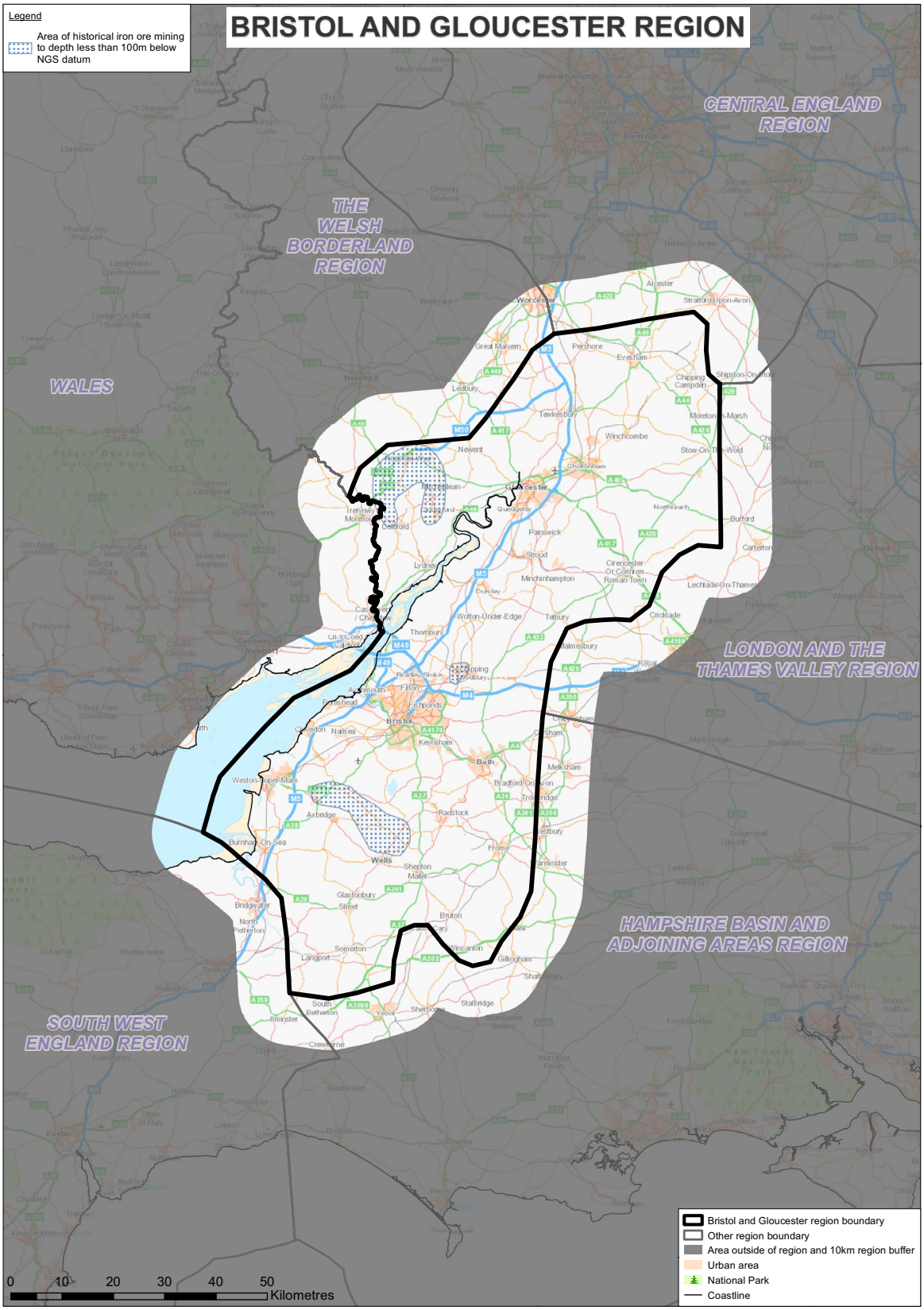
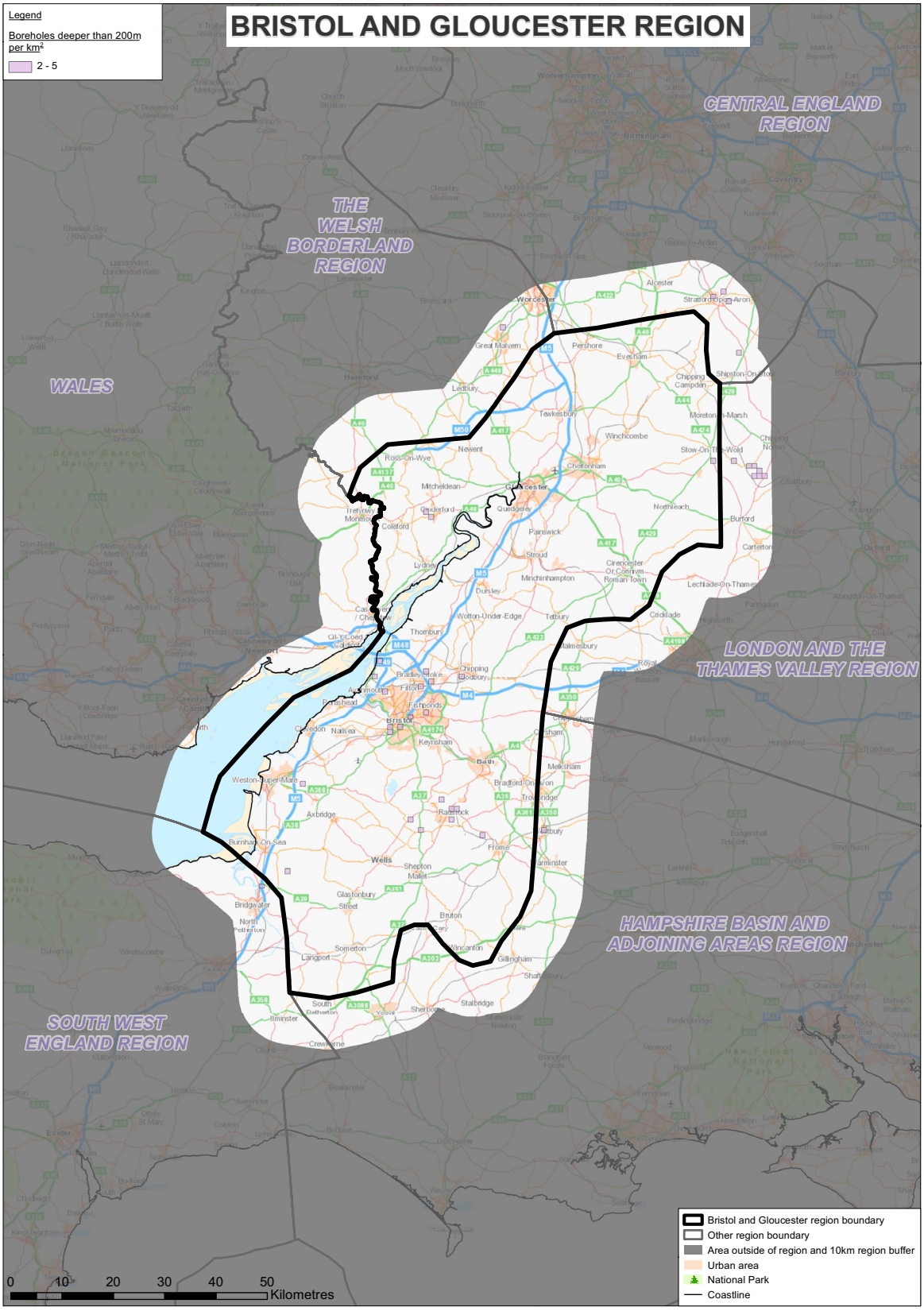


Figure 8 Areas in the Bristol and Gloucester region with concentrations of deep exploration boreholes.



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.

Anglian
A glaciation event during the last ice age about 450,000 years ago, where ice sheets extended as far south as the Severn and Thames Estuaries.

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.

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

Dolomite
Magnesium carbonate mineral which often is found in limestones.

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.

Evaporite sequences
A layering of different types evaporite minerals that forms due to the differing composition of the water that is evaporating to form them.

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.

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'.

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.

Lithology

The physical properties of rock types.

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.

Shale

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.

Solution mining

A technique to extract soluble minerals out of the ground by pumping liquids into a deposit, dissolving the target minerals, returning the water to surface and reprecipitating the mineral. Solution mining for rock salt is carried out in the UK and for other commercially valuable minerals around the world.

Radioactive Waste Management

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