South-west England region

This account provides a broad perspective of the geology of South-west England, encompassing the counties of Cornwall, Devon and part of Somerset. It is bounded by the Atlantic, Bristol Channel and the English Channel and a line from Bridgwater through Crewkerne to Lyme Regis. The region is predominantly rural with the major cities and towns including Penzance, Truro, Newquay, Plymouth, Torquay, Exeter, Taunton and Barnstaple. Figure 1 provides a geological sketch map of this region showing the rock types occurring in relation to the major towns and cities. This account outlines the geology to a depth of at least a kilometre and summarises the current and historical use of the geological resources in the area.

The near-surface geology of the region is well known due to the many quarries, mines, coastal cliffs and shallow boreholes. The region has been quarried for slate, granite and limestone for building stone. The extractive industry has also worked sands and gravels and the region has produced large quantities of china clay (kaolin). Historically, Cornwall and Dartmoor include some of the most important metalliferous mining districts in the British Isles, and these have been particularly important sources of copper, tin and arsenic from prehistoric times up to the twentieth century. More locally tungsten has been mined on Dartmoor in the past and new mining is in prospect, while there has been historic production of silver and lead on Exmoor.

At greater depths, below about 200 m, our understanding relies heavily on information from former mines and a few deeper boreholes. The majority of the boreholes are clustered in the south-west of the region and were drilled for mineral exploration aimed at the minerals associated with the granites, which are solidified remains of bodies of molten rock or magma, similar to those which lie beneath many active volcanoes today at depths of a few kilometres. The very deepest of these boreholes go down over a kilometre. Other deep boreholes were drilled to explore for hydrothermal energy, oil and gas. Patterns of the Earth’s gravity and magnetic field, the latter measured with great sensitivity from aircraft, also give us clues as to the deeper geological structure of parts of the region and in particular the subsurface extent of the granite.

With the exception of the easternmost parts, in most of the region the rocks do not contain sufficient water to provide a source for drinking water supply and therefore almost all the water for the region comes from surface rivers and reservoirs; however, small domestic supplies are abstracted in some areas. The region does not contain valuable oil, gas or coal deposits at depth; consequently there is limited information from exploration for these commodities. However, some geophysical surveys which provide information on the rocks by sending sound waves through the ground (seismic surveys) have provided data for the southeastern part of the region around Lyme Regis, where it is useful to help interpret the deeper geological structure.
Figure 1 Geological sketch map showing the range and distribution of different rock types in the South-west England Region, in relation to the major towns and cities. The extent of the region is shown on the inset map of the United Kingdom.
**Geologically recent surface deposits**

Most of the region has few to no recent surface deposits. Those that do occur comprise sands and gravels developed along the larger river systems, and in the east of the region flinty gravels overlie Chalk bedrock. Most rivers in the region flow south to the English Channel. The poorly drained and wet higher parts of the region, usually above 300 m, contain blankets of peat a few metres thick. This region lay beyond the extent of the ice-sheets that have dominated the evolution of the British landscape over the past 2-3 million years.

**Bedrock geology**

Below the recent surface deposits and extending all the way to the surface wherever such deposits are absent are older rocks which geologists broadly split into two distinct types:

- **The sedimentary bedrock** formed from around 25 to 300 million years ago and is found in the east of the region. Most of the bedrocks were formed as layers of sediments which were deposited in shallow seas, deserts and vast river systems in times when Britain lay closer to the Equator and the climate and landscape were very different from those of today.

- **The basement rocks** occupy much of the peninsula and underlie the sedimentary bedrock in the east, they were deposited mainly in deep to shallow seas from 315 to 410 million years ago. Subsequently, these rocks have been folded and affected by high pressure and temperature (metamorphosed). This has resulted in characteristics, such as the development of slate, being superimposed on their original sedimentary features. Although the slates of Devon and Cornwall are broadly similar to those of Wales, the deposits are distinctly younger and the metamorphism formed in a separate period of earth movements that ended around 310 million years ago. Included within the basement rocks are a series of bodies of granite, formed by the solidification of molten rock or magma, intruded into the sedimentary layers at depth. All the granite bodies, from Dartmoor to the Isles of Scilly, have been shown by geophysical surveys to be connected together deep below the surface. Where they do occur at the surface they generally give rise to high moorland. In south Cornwall there are also crystalline basement rocks at the Lizard Peninsula and at Start Point.

This division of the geology is somewhat arbitrary, but has been chosen to distinguish between rocks with very different physical characteristics and ability to retain groundwater.

The geological structure of the area comprises a sequence of sedimentary rocks underlain at depth by very old crystalline basement rocks and punched through from below by the granite bodies through the south-west of the region. The metamorphosed basement rocks in the west of the region have been down folded into a trough-like form that geologists call a syncline. This means that the oldest rocks at the bottom
of the sequence occur at the edges of the syncline for instance in the north around Ilfracombe and south around St Austell, while the younger rocks occur in the centre of the region for example around Bude and Okehampton.

During the period of folding and the time of emplacement of granite that followed, the basement sediments were deeply buried beneath mountains, and no sediments were deposited above them. After millions of years of erosion however, the landmass subsided and the sedimentary bedrock of the east of the region were deposited on top. This means that the lowest of these sedimentary rocks directly rest on a range of different older basement rocks across the region. This situation where younger rocks rest directly on rocks of different older ages because of uplift and erosion is referred to by geologists as an unconformity. Figures 2 and 3 are vertical sections through the geology, referred to as geological cross-sections, which illustrate the variations in geology across the region.

**Figure 2** Schematic cross-section of the geology of the South-west region from St Just to Crewkerne. The alignment of the section and key are shown on Figure 1.

**Figure 3** Schematic cross-section of the underlying geology of the South-west region from Exmoor to Start Point. The alignment of the section and key are shown on Figure 1.
Sedimentary Bedrock (Eastern area)

These rocks generally lie to the east of a line between Watchet and Torquay, although there are also narrow developments stretching farther west around Hatherleigh, Tiverton and Great Torrington. These sedimentary rocks are younger than 300 million years old and are tilted gently towards the east so their base reaches a depth of over 1600 m, about 6 km northeast of Lyme Regis. They were deposited on deformed sedimentary rocks similar to those that occur at the surface further west. These younger sedimentary bedrocks reach total thicknesses in excess of 1500 m and extend to depths greater than 1500m below sea-level in the eastern part of the area.

The youngest deposits are approximately 55 to 25 million years old (Palaeogene sediments) and are of very restricted extent. They comprise clay, sand and silt layers deposited in small lakes and rivers and occur between Bovey Tracey and Newton Abbot and also farther west about 5 km south of Great Torrington. These deposits are relatively soft and form low-lying ground. They have infilled rapidly subsiding hollows or basins in the older rocks that were formed by the movement of geological faults. Although these basin areas are relatively small, the deposits have been proved to extend to at least 600 m below sea-level in parts of these areas. Much of the sediment has been derived by erosion of the Dartmoor granite mass, and the clay deposits in the Bovey Tracey area have been an important source of clay for ceramics.

The main Eastern part of the region includes a sequence of gently-dipping sedimentary layers (Cretaceous sediments). These are composed of sandstones and clays capped by Chalk, 110 to 90 million years old, occurring in the area south of Taunton. The Chalk is a fine grained white and grey rock composed of minute grains and fossils made of calcium carbonate, it caps the tops of the hills along the coast between Sidmouth and Lyme Regis and inland to the area around Chard reaching a maximum thickness of 80 m.

The Chalk was deposited in a sea which spread westwards across the south of England and so it rests on successively older rocks through Dorset and on into Devon. Sandstones were deposited first, followed by chalk as the sea deepened. The underlying sandstones of the Selborne Group are also a good source of drinking water and where the Chalk lies above them water can flow between the two layers. These layers rest upon a sequence of slightly older sedimentary rocks ranging from about 300 to 185 million years old and tilted gently to the east, with the oldest rocks at the surface in the west around Torquay and the younger ones at the surface farther east around Lyme Regis.

The youngest of these tilted deposits comprise Jurassic sediments, 200 to 185 million years old, that include mainly limestones and underlying mudstones of the Great and Inferior Oolite and Lias Group, respectively.
These form an impressive part of the World Heritage Site along the Devon-Dorset coastline between Exmouth and Bridport, an area known as the Jurassic Coast. These layers extend northwards but are absent in the area between Taunton and Bridgwater. They are then present again on the north coast of the region between Watchet (Figure 4) and 3 km north of Bridgwater. These rocks reach a depth of 366 m below sea-level around Crewkerne in the east of the region. Oil shale was discovered in 1900 on the coast near Watchet, but commercial extraction was abandoned due to the high sulphur content.

![Grey Lias Group mudstones overlying red Mercia Mudstone with white gypsum in the foreground, near Watchet.](image)

**Figure 4**  Grey Lias Group mudstones overlying red Mercia Mudstone with white gypsum in the foreground, near Watchet.

To the west of the area occupied by the Lias, between Sidmouth and Seaton and extending northwards to Taunton and Bridgwater and then along the north Somerset coast to Minehead, is a thick succession of red mudstones which locally contain gypsum (Figure 4). These are known as the Mercia Mudstone, which is nearly 500 m thick and extends eastwards beneath the Lias to depths of about 870 m to the south of Crewkerne.

The oldest strata in this sequence of sedimentary rocks were formed in part of an extensive desert in which rare storms washed rock debris into basins and huge scree slopes accumulated at the foot of mountains,
forming a succession of red sandstones with pebble layers (Figure 5) and mudstones. This was a landscape with active volcanism and both lavas and the sites of small volcanoes are found around Exeter. These were probably formed at the end of the period of magma intrusion that gave rise to the granite masses found further west. The upper part of this sequence of rocks, known as the Sherwood Sandstone, is approximately 250 m thick. These rocks are present at the surface from east of Exmouth in the south to Minehead in the north. The pores or voids between the sand grains and pebbles allow water to flow easily through the rock as well as flowing through fractures within it, making this unit a locally important aquifer used for drinking water supply.

![Figure 5](image)

**Figure 5**  *Sandstones with pebble layers of the Sherwood Sandstone, Burlscombe, near Wellington.*

**Basement Rocks**

These rocks occur at surface in most of the area to the west and south of a line from Watchet to Torquay. They comprise rocks of sedimentary origin that have been intensely deformed, then intruded by granite bodies. They are marked by a landscape that is dominated in the north by long east-west trending valleys and ridges. Harder rock layers form the long ridges separated by valleys of softer rock (Figure 6). These Devonian and Carboniferous strata were deposited between about 410 to 315 million years ago.
The ridges are commonly formed by harder sandstones. Towards the top of this sequence of sediment layers, the Carboniferous rocks are rich in sandstone, siltstone and mudstone. The youngest sediments accumulated around Westward Ho! near Bideford in a swampy environment, with river-borne sediments. This produced coal-bearing mudstones and sandstone with thin developments of lignite and coal that were worked in small pits until 1969. The underlying sandstone and mudstone sequence, known by geologists as the Culm (Figure 7), now occupies the greater part of central Devon and the north Cornwall area around Bude. It lies in the heart of a large down fold or syncline, but as well as this large fold structure, the rocks are intensely deformed throughout and the muddy beds have acquired many of the characteristics of slate. The Culm sedimentary rocks are estimated to reach depths in excess of 1000 m through the centre of this large syncline in the area around Hatherleigh. It represents the deposits within a large lake or shallow sea. Beneath the Culm, the oldest of the Carboniferous rocks comprise mainly black mudstones with local development of hard chert, deposited in a deep sea, with localised eruptions from volcanoes represented by lavas and tuffs within the sediments.
During the Devonian the region formed a deep sea with high ground draining from the north bringing large quantities of sediments into the sea. These deposited pebble beds, sandstones and mudstones with some volcanic rocks, and where the sea was shallow, in central and eastern Devon and around Torquay, limestones were deposited. The Devonian Rocks that lie at surface in the north of this area typically comprise coarser grained and thicker sequences of sandstone that retain many of their sedimentary features and are much less deformed than rocks of the same age present to the south and west (Figure 8). Farther south these rocks become mainly mudstones with some limestones that were deposited in a quiet deeper part of the sea which covered this area. Volcanic activity at the time also produced widespread flows of lava within this sequence of rocks, particularly further west. These are preserved from the north coast of Cornwall, where they form the towering cliffs of Pentire, Newquay; a second strip extends from the south of Bodmin Moor past Liskeard and Plymouth to Torquay.
The basement rocks have been extensively folded and faulted in the millions of years since they were first formed; they are estimated to be over 4000 m in total thickness, with the sequence compressed by pressure from the south resulting in folds which are aligned with an east-west trend. The forces were sufficient to bend the strata over itself resulting in some layers now lying upside down. In the south, where the compression was the greatest it was strong enough to break the rocks creating faults and shunting slabs of the older rocks northwards over younger rocks. In some places the compression and folding resulted in temperatures and pressures high enough to “bake” the rocks so that they now have a slaty character allowing them to break easily in one direction leading to the use as roofing slates, as at Delabole, 4 km west of Camelford.

**Granite intrusions**

Granite igneous intrusions occur throughout the region, except in the north and east. As granite is a hard crystalline rock it is not easily eroded and forms rugged upland areas. At surface the rock weathers into the form of the distinctive tors (Figure 9), as seen on the top of areas like Dartmoor, forming hills over 300 m high, including the two highest peaks in southern England.

The granite intrusions formed towards the end of the phase of compression and earth movement that folded the surrounding basement rocks about 295 million years ago. A large molten mass of magma rose

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**Figure 8**  Tightly folded and overturned Devonian mudstones near Ilfracombe, north Devon.
from within the Earth’s crust and ascended to near the surface where it spread out to form a long cylindrical body extending from Dartmoor to the Scillies. Extending upwards from this body, six smaller pinnacles rose still further and now form the granite moors and high ground of Dartmoor, Bodmin Moor, north of St Austell, west of Falmouth, Penzance and the Isles of Scilly. The rocks into which this hot magma intruded were locally baked by the intense heat, changing their nature to harder re-crystallised rocks. In some places they were also shot through with mineral veins by fluids released from the crystallising magma.

We can infer the shape and extent of the main granite body (geologists call it a batholith) at depth from the distribution of the granite pinnacles at surface and from regional magnetic and gravity surveys. It seems the main granite body has an elongate shape oriented NE-SW and a very irregular top surface, which locally extends to depths greater than 1 km. It is uncertain exactly how thick the granite mass is but it is likely to be several kilometres.

![Typical granite tor at Blackingstone Rock, in the Dartmoor National Park.](image)

The granite pinnacles that rise to the present-day surface have many associated mineral veins which were formed by the cooling of mineral rich liquids associated with the magma as it was emplaced. These have been mined for tin, copper, tungsten, lead and small amounts of gold and silver. The main areas of mining were around St Just, Tregonning and Gwinear, Wendron, Camborne and Redruth, Gwennap, St Agnes, Caradon and the Tamar Valley. Some of the mines in these areas reach depths of over 500 m and exceptionally the Dolcoath Mine reached a depth of 1000 m.
Where the granite was altered by hot water circulating through it as it cooled, some of the minerals were altered to clay. This clay is very fine and white and is commonly known as china clay (kaolin), it is ideal for the production of fine porcelain. Large surface excavations for china clay occur near St Austell, Lee Moor and Camelford.

The Cornish granites and surrounding areas are recognised as one of the areas in the UK with the greatest potential for the exploration and development of geothermal energy as they are hot in comparison to the surrounding rocks. This heat is predominantly produced by the decay of natural radioactive minerals in the rock. Granite is a crystalline rock with interlocking crystals which do not allow groundwater to flow through it, however, the granites masses contain many natural fractures and near the surface these can permit water flow.

Older basement rocks

Older rocks which have been faulted against the main area of basement rocks are located on the Lizard peninsula and at Start Point (Figure 10). The Lizard is made up of a complex range of crystalline igneous rocks, many formed at and beneath an ancient ocean floor. They are darker and denser than the younger granite. These fragments of ancient ocean floor, of similar age to some of the older sediments to the north, have been thrust up from depth by the compression and earth movement described above. In the process, still older Lower Palaeozoic sedimentary and igneous rocks have been caught up in the faults.

Figure 10  Highly deformed metamorphic rock of the Start Point Complex.
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