Wales

This account provides a broad perspective of the geology of Wales, which comprises a diverse landscape that includes the mountains of Snowdonia and the Brecon Beacons, the upland plateau of Central Wales and the flatter landscapes of the valleys and coastal areas, including the Gwent Levels south of Newport, Vale of Glamorgan and island of Anglesey. 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 geology near the surface is well known from abundant natural outcrops of rock, such as coastal cliffs and mountain crags, as well as quarries and mines. However, there are few deep boreholes in Wales such that, at greater depths, the understanding of the geology is largely conceptual, based on projection of surface measurements and observations to depth. Exceptions to this are the former coal mining areas of North and South Wales, where a number of deep shafts and boreholes have provided insights into the deep structure. Geophysical seismic surveys have provided some information on the rocks by sending sound waves through the ground but they are very limited and only cover parts of the South Wales Coalfield and Vale of Glamorgan.

Geologically recent surface deposits

Much of Wales is covered by geological deposits of relatively recent origin, formed over the past 2 to 3 million years and spanning the Ice Ages and Interglacial periods. These are known as superficial deposits and include gravelly clays and sand and gravel laid down during the last Ice Age, sand, silt and gravel deposited by rivers along valley floors over the last 10,000 years and peat bogs that formed mostly in upland areas. Some of these shallow deposits locally form greater thicknesses up to 50 m in areas such as the Lower Swansea Valley, which has been scoured out by the action of glaciers. Most of the superficial deposits are soft and easily eroded, as they have not been deeply buried and consolidated to form strong rocks.
Figure 1  Geological map showing the range and distribution of different rock types in Wales, in relation to the topography and major towns and cities. Wales is identified on the inset map of the United Kingdom.
Geology at depth

Below the superficial deposits, or with just a cover of soil where such deposits are absent, are older rocks which geologists broadly split into two distinct types:

- The **sedimentary bedrock geology** is composed of quite hard rocks which were deposited up to 415 million years ago as layers of sediment in shallow seas, coastal plains or by the action of ancient river systems in times when Wales lay closer to the Equator and the climate and landscape were very different from those of today.

- The **basement geology**, which underlies the bedrock, is over 415 million years old and mainly comprises harder, denser rocks which have been strongly compacted and folded. Most of the basement rocks comprise strongly folded and faulted grey mudstones, siltstones and sandstones. Other basement rocks include both rocks that are products of volcanic activity (volcanic rocks) or formed from the solidification of molten rock deep below the surface (igneous intrusive rocks) and rocks which may have started as either sediments or intrusions but have subsequently been changed into a different form by the high temperatures and pressures which they have been subjected to since (metamorphic rocks), such as those exposed in parts of Anglesey.

In the course of the past 540 million years there have been periods when the area of Wales formed a landmass and was being eroded, and other periods when it was sinking and new layers of sediment were being deposited. The history of erosion and deposition has not been the same in all parts of Wales. The oldest sedimentary rocks are sandstones, siltstones and mudstones. These rocks were buried and deformed by the forces of continental plates moving against each other.

Subsequently, younger sequences of sedimentary rocks, including limestones, sandstones and clays, were laid down. Although in some parts of Wales, sediments continued to be deposited relatively constantly, in most areas deposition stopped and instead uplift and erosion took place for tens of millions of years. As a result when deposition restarted the next layer was laid down on a variety of different older sediments. 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.

The geology of Wales is also affected by geological faults where the rocks on each side of the fracture have moved relative to one another. The relative movement of the rocks on either side of some of these faults can be very significant resulting in dramatic changes in geology over short distances. These include the Bala Fault which runs 50 km in a northeast to southwest direction through the town of Bala and the Welsh Borderland Fault Zone which is a zone of faulting and associated folding which runs northeastwards through Wales from Pembrokeshire through Carmarthenshire and Powys into Shropshire.
Figures 2, 3 and 4 are vertical sections through the geology, referred to as geological cross-sections, which illustrate the variations across the region.

**Figure 2** Schematic cross-section of the geology of Anglesey and Northwest Wales. The alignment of the section and key are shown on Figure 1.

**Figure 3** Schematic cross-section of the geology of Central Wales. The alignment of the section and key are shown on Figure 1.

**Figure 4** Schematic cross-section of the geology of South Wales. The alignment of the section and key are shown on Figure 1.
Individual areas

For the purposes of this account, Wales has been subdivided into six geographical areas that are characterized by contrasting underlying geology: Anglesey and Arfon, Northwest Wales, Central and West Wales, Southeast Wales, the North Wales Coalfield and South Wales.

Anglesey and Arfon

The Island of Anglesey, the northern Lleyn Peninsula and the Caernarfon area is mainly low-lying with a few hills in the Lleyn Peninsula. The main towns include Holyhead, Bangor and Caernarfon.

Sedimentary Bedrock

The youngest rocks in the area comprise the Coal Measures comprising sandstones, mudstones and coal seams that were deposited between around 360 to 300 million years ago. The Coal Measures formed from vast quantities of sediment being transported by large river deltas. Occasionally the tops of these deltas were exposed, which allowed massive swampy forests to develop. After burial the vegetation from these forests was compressed to produce layers of coal. These rocks extend as a band across from Malltraeth Bay to Red Wharf Bay and on the margins of the Menai Strait. The Coal Measures are underlain by Carboniferous Limestone, deposited in shallow tropical seas. Some of the rock layers contain enough water to be exploited for drinking water supply, such rocks being referred to as aquifers. The principal aquifer in the area is the Carboniferous Limestone, however the abstraction of small volumes of water from the older basement rocks for private supply is also widespread. In the vicinity of Lligwy Bay the oldest sedimentary bedrock comprises a sequence of red sandstones, mudstones and pebble beds that were deposited by rivers between around 415 to 400 million years ago.

Basement rocks

The sedimentary bedrock rocks is underlain by older sedimentary rocks that were deposited between around 470 to 430 million years ago in layers of mudstone and sandstone in a deep sea. These are host to historically worked copper deposits at Parys Mountain on Anglesey. These basement rocks occur at surface across much of north and west Anglesey and Arfon and are thought to extend to depths of greater than 1 km throughout the area.

These basement rocks are largely underlain by a complex of rocks that were formed between around 700 to 480 million years ago. These include:

- the strong rocks which have been changed into a different form by high temperatures and pressures (metamorphic rocks) that are present across much of Anglesey;
• the intrusions of molten rock that then cooled and solidified to form crystalline rocks such as granites and now occur at surface in a band across Central Anglesey and around Caernarfon; and
• thick units of volcanic tuff erupted from ancient volcanoes present between Bangor and Llanberis.

Together, all of these rocks have been contorted during several phases of earth movements so that the layers are often tightly folded and steeply inclined, with individual rocks which split open readily like slate.

![Contorted basement rocks (schists) at South Stack, Anglesey.](image)

**Figure 5**  Contorted basement rocks (schists) at South Stack, Anglesey.

**Northwest Wales**

The geography of this area is dominated by the mountains of Snowdonia and the Rhinogs, where the landscape has been deeply eroded by glaciers. This area extends from the Menai Strait in the north to the major break in the geology – the Bala Fault which runs in a northeast to southwest line from Llangollen to Aberdovey. The eastern boundary of this area is taken where younger bedrock layers are found at the surface. The area is predominantly rural the main settlements include Conwy, Llandudno, Betws-y-Coed, Dolgellau, Harlech and Ffestiniog.
Sedimentary Bedrock

The youngest rocks in the area comprise a succession of soft silt and clay (Palaeogene), underlain by harder mudstone and siltstone with limestone layers (Lias), which were deposited up to 250 million years ago. These are preserved in a small area on the coastal plain between Barmouth and Harlech, and proven in a very deep borehole (Mochras) near Llanbedr. Elsewhere layers of Carboniferous Limestone form the prominent hills around Llandudno and in a ridge extending from Colwyn Bay to Ruthin; these are host to historic mineral workings. In the east of the area, the Vale of Clwyd contains a block of red sandstones deposited between around 320 to 200 million years ago, which has moved downwards due to geological faults or breaks in the rock. This layer is a major aquifer due to the spaces between the sand grains in these sandstones and provides a significant public water supply.

Basement rocks

Youngest basement rocks (Silurian), exposed in the east of the area, generally comprise thick units of sandstone and mudstone and extend south of the Bala Fault into mid-Wales. These rocks are underlain by dark grey slates and sandstones deposited in an ancient sea between 475 to 445 million years ago and are thought to extend to depths of greater than 1 km. They alternate with thick layers of volcanic rocks with small intrusions mainly of granite. Here the volcanic tuffs are generally resistant and form the main mountain peaks of Snowdonia (Figure 6). Copper mineralization, such as that at Coed y Brenin, is present within the sediments and has been mined in the past. These are underlain by a sequence of sedimentary rocks that were deposited between around 550 to 480 million years ago and form the central part of the Rhinogs. The lower part of this sequence is dominated by strong thick sandstone layers that are overlain by slaty mudstones with thin sandstones. These rocks are host to the gold and manganese deposits that have been mined in this area in the past. The oldest rocks in the area comprise volcanic tuffs, erupted from ancient volcanoes, proven in a borehole but not exposed at surface.

The basement rocks are tightly folded and are cut by a dense network of faults and fractures. Throughout the area they form local aquifers in which the water flows along these fractures and from which abstraction of small private water supplies is widespread.
Central and West Wales

This area contains the incised upland area of the Cambrian Mountains that extends southeast of the Bala Fault and northwest of the Welsh Borderland Fault, the latter is a network of major fractures that extend from Pontesbury in Shropshire southwestwards as far as St. Brides Bay in Pembrokeshire. The northeastern boundary of this area is coincident with the Welsh Border. No sedimentary bedrock lies on top of the basement rocks in this area.

Basement rocks

The youngest basement rocks form layers deposited between around 460 to 420 million years ago, comprising thick units of marine mudstone and sandstone. In parts of Pembrokeshire and the Berwyn Hills layers of volcanic rock are also present. Volcanic rocks are also exposed adjacent to the Welsh Borderland Fault at Llanwrtyd Wells, Builth Wells and Shelve. In the southwest of the area and in the Berwyn Hills to the northeast, mudstone, limestone, sandstone and tuffs were deposited between around 700 to 460 million years ago are exposed at surface and are thought to extend at depth beneath the area. The oldest rocks exposed in this area comprise intrusive igneous rocks, volcanic rocks and a range of sedimentary rock formed between around 700 to 600 million years ago and exposed in places within the Welsh Borderland Fault.
The basement rocks have been folded during earth movements and are often steeply inclined with a slate-like appearance. The rocks are typically strongly fractured and cut by many faults. Although there are no major aquifer rocks in the area, small scale groundwater abstraction for small private supplies from these heavily fractured rocks is widespread. The rocks of the Cambrian Mountains are host to Lead-Silver mineralization that was worked extensively until the early 20th Century. Gold mineralization at Dolaucothi was exploited sporadically between Iron Age and Edwardian times.

**Southeast Wales**

This area encompasses the rural mainly upland area located southeast of the Welsh Borderland Fault, bounded on its southern margin by the edge of the South Wales Coalfield with the eastern boundary located along the Welsh Border. Much of this area comprises a series of steep escarpments such as Mynydd Epynt and the Brecon Beacons, with intervening slopes forming rolling farm land. There are few large settlements, the main towns include Brecon and Abergavenny.

**Sedimentary Bedrock**

The only sedimentary bedrock in this area is referred to by geologists as the Old Red Sandstone, which was deposited in deserts and rivers between 420 and 360 million years ago. This comprises a sequence that is several kilometres thick of reddish sedimentary rocks that dip gently toward the south and southeast and can be seen in the escarpments of the Brecon Beacon mountains (Figure 7).

**Basement rocks**

In the west of the area, units of mudstone, sandstone and limestone deposited between around 430 and 420 million years ago are exposed. These are thought to pass at depth beneath the Old Red Sandstone. Although these rocks do not currently constitute a major aquifer in Wales, the abstraction of groundwater for private supply is widespread.
North Wales Coalfield

The North Wales Coalfield is defined by a north - south surface exposure of Carboniferous Limestone, Millstone Grit and Coal Measures that extend from Deeside south through Wrexham to Oswestry. The geography is dominated by a prominent ridge of Carboniferous Limestone in the west and falls gently eastwards toward the low ground of the Cheshire Plain of the Central England region in a series of low ridges.

Sedimentary Bedrock

The youngest Sedimentary Bedrock is the Coal Measures, comprising a thick, densely faulted sequence of alternating grey mudstones and sandstones with thin coal seams that together make up the formerly productive part of the North Wales Coalfield. These rocks formed from vast quantities of sediment being transported by large river deltas. Occasionally the tops of these deltas were exposed, which allowed massive swampy forests to develop. After burial the vegetation from these forests was compressed to produce layers of coal. The upper part of this sequence comprises red sandstone and mudstones without

Figure 7  Old Red Sandstone rocks of the Brecon Beacons.
economic coal layers. The Coal Measures pass down into layers of sandstones and mudstone collectively known as the Millstone Grit. The lowest part of the succession comprises layers of Carboniferous Limestone (Figure 8) that generally dip toward the east and extends under the rest of the area at depth. As well as exploitation of coal seams, the limestone is host to mineral deposits of lead that were widely mined in the past. More recent interest in the Coal Measures has focused on their potential as a resource for gas. As well as its mineral potential, the presence of significant fractures in the Carboniferous Limestone means that it is a locally important minor aquifer that represents a significant source of public water supply.

**Basement rocks**
These rocks underlie the whole area at great depth. They comprise strongly folded and faulted mudstones and sandstones like those exposed in the east of the Northwest Wales area.

*Figure 8  Carboniferous Limestone sedimentary rocks forming the escarpment of Mynydd Eglwysseg, Llangollen.*
South Wales

The South Wales area extends eastwards from Pembrokeshire, south of the Welsh Borderland Fault, then runs along the northern flank of the South Wales Coalfield to the Welsh Border in the east. Much of the area comprises an upland plateau deeply incised by the rivers of the South Wales Valleys. The contrasting low-lying coastal plain of the Gwent Levels, Newport and Vale of Glamorgan are also included within this area. The main towns and cities in this area include Cardiff, Swansea, Neath, Bridgend, Newport and Merthyr Tydfil.

Sedimentary Bedrock

The youngest Sedimentary Bedrock comprises mudstones and limestones (Figure 9) deposited between 200 to 150 million years ago that underlie much of the Vale of Glamorgan. Along the northern margin of the Severn Estuary, a complex landscape is developed of older sedimentary bedrock layers, including red pebbly sandstones, and mudstone deposited in rivers and deserts between 300 and 200 million years ago. These layers are exposed between Chepstow and Barry and also around Porthcawl.

The main part of the South Wales Coalfield forms a large basin-like down-fold of sedimentary rock layers with the youngest and highest layers coming to the surface in its central part and the progressively older layers exposed around the rim of the basin. In general the Coal Measures succession comprises upper division dominated by thick sandstone beds with subordinate mudstones and only thin coal seams and lower layers dominated by mudstone with scattered sandstones and abundant coal seams. These pass down into a sequence of mudstones and sandstones (Millstone Grit). Layers of Carboniferous Limestone form a distinctive rim around the Coalfield and are also present beneath, including parts of south Pembrokeshire, much of the Gower Peninsula, and parts of Monmouthshire.

This area is cut by numerous faults of which those aligned northeast-southwest along the lines of the Swansea and Neath valleys are the most prominent. The rock layers exposed in south Pembrokeshire and the Gower Peninsula have been more strongly affected by earth movements and are contorted into a series of fold structures that are strongly disrupted by west-east trending geological faults. As well as widespread deep and shallow coal mining, historic iron ore mining and lime processing took place in the northern parts of the Coalfield. Being soluble, the Carboniferous Limestone has been dissolved by rainwater percolating through it to form extensive cave systems, such as those in the Ystradfellte area. The Carboniferous Limestone is a major aquifer in this area, with most water flow along caves and fractures and it provides a significant public supply. Millstone Grit and Coal Measures sandstones also represent minor aquifers. Although abstraction for private supply is not uncommon, this is limited in the Coal Measures, partly due to
contact with the abandoned mine workings. The oldest rocks exposed at surface in the area comprise the Old Red Sandstone formed of red mudstone and sandstone exposed in a narrow belt in south Pembrokeshire but occupying a more extensive tract eastward, and continuous with that of the southeast Wales area.

![Cliffs of thinly interlayered Jurassic limestone and mudstone sedimentary rocks near Dunraven east of Porthcawl.](image)

**Figure 9** Cliffs of thinly interlayered Jurassic limestone and mudstone sedimentary rocks near Dunraven east of Porthcawl.